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PRINCETON APPLIED RESEARCH CORPORATION

PRINCETON, NEW JERSEY

INSTRUCTION MANUAL

VOLTAGE/CURRENT REFERENCE SOURCE

MODEL TC-602CR

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This manual applies specifically to Model TC-602CR Serial No. 227

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CAUTION! WHEN USING EXTERNAL SENSING.
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9. SCHEMATICS

1. GENERAL

The PAR Model TC-602CR transistorized, regulated DC constant voltage and constant current power supply is designed to provide the best obtainable stability, regulation, reliability and freedom from noise and ripple. It features short-circuit protection, remote programming and sensing, digital voltage and current selection, overload and out-of-regulation indication, and high efficienty. A continuously variable control (vernier) provides a resolution, in setting of the output, equivalent to two more digits on the Kelvin-Varley divider. It is ideally suited to both general laboratory use and such applications where its unique features and specifications make its use mandatory.

The Model TC-602CR is a rack-mounted unit for use in systems as a primary ultra-stable source of power, or as an integral part of check-out and calibration equipment.

9000. ±

555 13500'

1000'

555 25

2. SPECIFICATIONS

1.0 INTRODUCTION:

This specification describes a voltage/current reference source Model TC-602CR which operates as either a zero to 60 volt constant voltage source or a zero to 2 amp constant current source and whose output is controlled by five decade thumb-wheel switches and a vernier after the least significant digit.

2.0 VOLTAGE MODE:

2.1 OUTPUT VOLTAGE: Zero to 60 volts.

2.2 OUTPUT VOLTAGE CONTROL: Output voltage is selectable by means of a series of thumb-wheel switches over two ranges: 0 to 60.000 and 0 to 6.0000 volts. These two ranges are selected by a range multiplier switch under CONST. I./CONST. V. heading. On each range, full scale voltage is obtained by selecting the full scale position of the OUTPUT SELECT control.

2.3 OUTPUT CURRENT: Zero to 2 amps.

2.4 ABSOLUTE ACCURACY

60 volt range	6 volt range
0.01% of setting or 1 mV whichever is greater	0.01% of setting or 100 uV whichever is greater

2.5 LOAD REGULATION: (no load to full load) Better than 0.0001% or 20 microvolts, whichever is greater.

2.6 LINE REGULATION: (10% line voltage change) Better than 0.0001% or 20 microvolts, whichever is greater.

2.7 OUTPUT IMPEDANCE: (at any load) At DC, less than 10 microhms. At 100 KC less than 100 milliohms. A monotonic increasing function of frequency.

2.8 RIPPLE: (at any load) Combined effects of all AC components appearing in the output is less than 50 microvolts rms at any setting.

2.9 SHORT TERM STABILITY: (100 hours at constant ambient temperature) after a 1 hour warm-up the output will not drift more than 0.001% or 20 uV on the 60 volt range and not more than 0.001% or 5 uV on the 6 volt range.

2.10 LONG TERM STABILITY: (1 year) $\pm$0.01% $\pm$100 microvolts.

2.11 TEMPERATURE STABILITY: At controlled ambient temperatures between 15°C and 35°C, output voltage will not drift by more than 5ppm/°C.

2.12 EXTERNAL SENSING: Sensing terminals are provided to regulate the voltage at a remote point.

2.13 TRANSIENT RESPONSE: Less than 25 microseconds to recover to within 10 millivolts of steady state voltage after application or removal of full load.

2.14 CASCADING: As many supplies as required may be operated in series observing the maximum 500 volts insulation rating under ISOLATION.

3.0 CURRENT MODE:

3.1 OUTPUT CURRENT: Zero to 2 amps.

3.2 OUTPUT CURRENT CONTROL: Output current is adjusted by means of a series of thumb-wheel switches over three ranges: 0 to 2.0000 amps; 0 to 600.00 milliamps; 0 to 60.000 milliamps. These three ranges are selected by a range multiplier switch under the CONST. I/CONST.V. heading.

3.3 COMPLIANCE VOLTAGE: Zero to 60 volts.

3.4 ABSOLUTE ACCURACY

60 mA Range	600 mA Range	2Amp Range
0.01% of setting or 1 uA whichever is greater	0.01% of setting or 10 uA whichever is greater	0.01% of setting or 200 uA whichever is greater

3.5 LOAD REGULATION: (Zero to maximum resistance)

60 mA Range	600 mA Range	2Amp Range
0.0001% of Full Scale	0.0001% of Full Scale	0.0002% of Full Scale

3.6 LINE REGULATION: (10% Line voltage change)

60 mA Range	600 mA Range	2Amp Range
0.0001% of Full Scale	0.0001% of Full Scale	0.0002% of Full Scale

3.7 RIPPLE: Combined effects of all AC components appearing in the output is less then 1 microamp peak-to-peak.

3.8 SHORT TERM STABILITY (100 hours at constant ambient temperature after 1 hour warm-up)

60 mA Range	600 mA Range	2Amp Range
0.001% or 60 nA whichever is greater	0.001% or 600 nA whichever is greater	0.001% or 20 uA whichever is greater

4.0 GENERAL:

4.1 INPUT POWER REQUIREMENTS: 105-125 volts or 210-250 volts; 50 or 60 cps.

4.2 EXTERNAL CONTROL: The output voltage or current may be controlled remotely over the full range with a 6K potentiometer.

4.3 ISOLATION: Output is isolated ±500 volts about ground.

4.4 SURGES: No overshoots during turn-on or turn-off under all load conditions.

4.5 OVERLOAD AND SHORT CIRCUIT PROTECTION: Output current will not exceed by more than 20% the full scale current under overload conditions. Prolonged short circuit operation will not damage the supply.

4.6 AUTOMATIC RESTORATION: Normal output is restored automatically upon removal of the fault.

4.7 OUT-OF-REGULATION INDICATOR: Indicator lights whenever output voltage or current is not being regulated in accordance with output setting.

4.8 WEIGHT: Approximately 36 pounds.

4.9 SIZE: Rack mounted cabinet, 19" wide by 5¼" high by 14" deep.

4.10 FINISH: Cadmium plated cover, light grey front panel.

NOTE: IT IS IMPORTANT TO ASSURE PROPER VENTILATION WITHIN THE UNIT. IF AIR FILTERS ARE ALLOWED TO BECOME DIRTY, THEY WILL RESTRICT THE FLOW OF AIR AND MAY CAUSE THE SUPPLY TO OVERHEAT. AIR FILTERS SHOULD BE VACUUM CLEANED AS REQUIRED.

3. DISCUSSION OF CHARACTERISTICS

INPUT

This supply operates over an input voltage range of 105-125 V.A.C. or 210-250 V.A.C. (determinded by power transformer primary connections as shown in Fig. 1, Section 7), 50-60 cps. single-phase, 180 VA (at maximum output). See Operating Instructions, Section 4.

OUTPUT (CONSTANT VOLTAGE OPERATION)

VOLTAGE: With the OUTPUT SELECT switch set to VAR, and the CONST.I./CONST.V. switch set to CONST. V., the available output is zero to 60 volts D.C. with this switch in the X10 position, and zero to 6 volts D.C. in the X1 position. In each case the output voltage is varied by means of five digital thumb-wheel switches having a resolution of one part in 10^5 of full scale at any setting. This resolution is extended to one part in 10^7 by means of a continuously variable vernier. The absolute accuracy of the voltage so set is as given in Item 2.4 in the SPECIFICATIONS section of this instruction manual. Voltage of 60 volts and 6 volts respectively are obtained with the OUTPUT SELECT switch set to F.S. With the OUTPUT SELECT switch set to zero, the output is zero volts.

REMOTE PROGRAMMING: The output voltage may be remotely controlled without loss of regulation by means of a 6K external voltage divider, with the OUTPUT SELECT switch set to EXT. With the CONST. I./CONST.V. switch in the X10 position, the range of output available is zero to 60 volts; with this switch in the X1 positions the range of output available is zero to 6 volts. The output voltage may also be controlled by an externally applied voltage. In the X10 range an output of 6.5 volts approximately is obtained for each volt input, and in the X1 range an output of approximately one volt is obtained for each volt input.

LOAD CURRENT: Currents up to a maximum of 2 amps may be continuously drawn from the supply. An electronic circuit instantaneously limits the available current (apart from a parallel 300 mfd. capacitor) at the 2 amp, 600 ma., 200 ma., and 60 ma. level, depending on the position of the current limit switch. If the load requirements are such that the current demand is greater than the selected limit, the supply will limit the current to the maximum value set and the OUT-OF-REGULATION light on the front panel will

indicate an out-of-regulation condition. Voltage regulation is immediately reestablished when the load current drops below the maximum value.

RIPPLE: Ripple in the output is less than 50 microvolts rms for any load below the limiting value of 2 amps. The ripple level is somewhat dependent on current; it is a minimum when the POSITIVE terminal is grounded to the case.

OUTPUT IMPEDANCE: The output impedance of the power supply at the output terminals (using the remote sensing connection to avoid lead resistance) is a monotonic increasing function of frequency and is given in the following table:

FREQUENCY	OUTPUT IMPEDANCE
D.C.	less than 10 microhms
10 cps	less than 100 microhms
100 cps	less than 1 milliohm
1 KC	less than 10 milliohms
10 KC	less than 10 milliohms
100 KC	less than 100 milliohms

REGULATION: To achieve the specified degree of regulation for line and load variations it is necessary to sense the voltage directly at the point of measurement. This is true even if the load is connected directly to the output terminals of the power supply. In this case a bus wire connecting the POSITIVE SENSE terminals to the POSITIVE OUTPUT terminals and another bus wire jumping the NEGATIVE SENSE terminals to the NEGATIVE OUTPUT terminal should be used. The VOLTAGE SENSE switch should be in the EXT. position.

SHORT CIRCUIT PROTECTION: The supply will withstand both continuous and intermittent short circuits without damage. Full voltage is reestablished when the short is removed. The short circuit current is the full scale limit set by the CURRENT LIMIT SWITCH.

METERING: The output current is indicated on the panel meter whose full scale reading is determined by the position of the CURRENT LIMIT SWITCH. The output voltage is indicated on the digital switches directly in volts.

NOTE: THIS METER PROVIDES ONLY A NOMINAL INDICATION OF THE OUTPUT CURRENT AND SHOULD NOT BE USED FOR PRECISION MEASUREMENTS OF LOAD CURRENT.

POLARITY AND GROUNDING: The output terminals of the power supply float with respect to ground and either positive or negative terminal may be grounded. Either output terminal may be connected to a point whose d c potential is

different from ground provided that the voltage between EITHER power supply output terminal and the power supply chassis ground does not exceed 500 volts D.C. Leakage resistance between either terminal and ground is approximately 100 megohms.

OUTPUT (CONSTANT CURRENT OPERATION)

This power supply has been designed to operate as a constant current as well as a constant voltage source. Either mode of operation is selected by the front panel CONST.I./CONST.V. switch.

CURRENT: With the OUTPUT SELECT switch set to VAR. and the CONST.I./CONST.V. switch set to CONST.I., the available output is:zero to 2 amps with this switch in the X1K position; zero to 600 milliamps in the X100 position and zero to 60 milliamps in the X10 position. In any case the output current is variable by means of five digital thumb-wheel switches having a resolution of one part in 10^5 of full scale at any setting. When the VERNIER is used the over-all resolution is one part in 10^7. The absolute value of the current at any setting will be within the tolerance given in Item 3.4 in the SPECIFICATIONS section of this instruction manual. Full scale output on all ranges, except the X1K range is obtained when the OUTPUT SELECT switch is set to F.S. Since the full scale setting on the Kelvin-Varley divider is 5.9999 volts or milliamps, the full scale setting (F.S.) on the OUTPUT SELECT switch, when the CONST. I. X1K range is used, would result in 6 amps full scale output. However, since the power supply limits the output current to 2 amps, such an output current is impossible. To obtain the 2 amp current output, set the OUTPUT SELECT switch to VAR., the Kelvin-Varley divider to 1.9999 and the Vernier fully clockwise, or 2.0000 and the Vernier fully counterclockwise. See Section 6 of this manual for description of circuits responsible for range selecting and limiting of output current.

With the OUTPUT SELECT switch set to 0, the output current is zero on all ranges.

REMOTE PROGRAMMING: The output current may be remotely controlled without loss of regulation by means of a 6K external voltage divider with the OUTPUT SELECT switch set to EXT. With the CONST.I/CONST.V. switch in the X1K position, the range of output current available will be zero to 2 amps; in the X100 and X10 positions the range of output current available will be 600 milliamps and 60 milliamps respectively. The output current may also

be controlled by an externally applied voltage. In the X1K range, an output of approximately one amp is obtain for each volt input. In the remaining two ranges, the output current per one volt input is proportionately smaller. (i.e. approximately 100 ma/volt in X100 and 10 ma/volt in X10).

COMPLIANCE VOLTAGE: Maximum compliance voltage available is slightly dependent upon current setting. However, at least 60 volts is available at all current settings.

RIPPLE: Ripple in the output is less than 1 microamp peak-to-peak at any current setting with the NEGATIVE OUTPUT terminal connected to chassis ground. With the output floating the ripple will appear considerably higher. THIS POWER SUPPLY CANNOT BE USED IN THE CONSTANT CURRENT MODE WITH THE POSITIVE OUTPUT TERMINAL GROUNDED.

NOTE: The VOLTAGE SENSE switch and its associated terminals are inoperative in the constant current mode. In this mode the operation of the supply is unaffected by the VOLTAGE SENSE switch.

METERING: The output current is indicated on a panel meter as well as on the digital thumb-wheel switches.

NOTE: THIS METER PROVIDES ONLY A NOMINAL INDICATION OF THE OUTPUT CURRENT AND SHOULD NOT BE USED FOR PRECISION MEASUREMENTS OF LOAD CURRENT.

OUT-OF-REGULATION INDICATOR: The OUT-OF-REGULATION light, which is the red light on the front panel, lights up whenever the output differs from the current setting.

CAUTION: Directly across the output terminals of this power supply is a 300 mfd. 150V. capacitor. Care must be exercised under certain conditions in order not to damage voltage or current sensitive external devices which are connected to the OUTPUT terminals.

(1) If the power supply has been operating at a relatively high voltage in the CONST. V. mode, is momentarily turned off, and then subsequently set at a relatively low voltage and immediately turned on again, the output voltage is initially determined by the voltage across the capacitor. That is, the output voltage does not build up from zero to the pre-set value but rather is determined by the discharge characteristic of this capacitor. Do not apply a voltage or current sensitive device as a load to the power supply under these conditions until the red OUT-OF-REGULATION light goes out, indicating that the output voltage is in accordance with the pre-set value.

(2) In the CONST. I. mode under open circuit conditions, this internal capacitor charges to the full scale (60V+) voltage independent of current setting. Upon completion of the external circuit this capacitor will discharge directly through the external load with a maximum surge current limited only by the resistance of this load in series with the current sensing resistor which is either 1, 10 or 100 ohms depending on the current range used. To avoid damage when connecting a load after the external circuit has been interrupted, either set OUTPUT SELECT switch at 0 and short circuit the OUTPUT terminals immediately before connecting the load, or connect sufficient resistance in series with the load to call for approximately 60 volts compliance voltage at the selected current.

However, note that in both the constant voltage and constant current mode there are no voltage or current overshooots during turn-off and turn-on, and no damage will result by turning the power supply on if the voltage or current has been pre-selected to a safe level for the particular load device the source is supplying.

4. OPERATING INSTRUCTIONS

This power supply is normally shipped with the power transformer primary wired for 117 V, 50-60 cps operation. If the instrument has been wired for 234 V operation, the line cord will bear a tag at the plug end to this effect.

NOTE: When changing from one line voltage to the other MOVE ONLY THE JUMPERS connected directly between the four primary terminals (nos. 1, 2, 3, & 4-see figure 1). DO NOT DISTURB any of the other wires connected to these terminals.

FUSE DATA:

	LINE	LOAD
	50 cps or 60 cps	50 cps or 60 cps
117 V AC	3A slo-blo	3A
234 V AC	1.5 slo-blo	3A

When shipped from the factory the instrument is correctly fused for either 117 V AC operation or 234 V AC operation, as the case may be.

The main power switch is in the primary input line. The meter panel light acts as a pilot light, and should be lit when the main power switch is turned on.

It is recommended that a one hour warm-up period be allowed to permit the reference voltage to reach optimum stability.

CONSTANT VOLTAGE OPERATION:

INTERNAL SENSING: When the VOLTAGE SENSE switch is in the INT. position the voltage is sensed internally at the OUTPUT terminals. No connection is required to the SENSE terminals for this mode of operation, and the voltage setting on the digital dial is available at the OUTPUT terminals either of which may be grounded, or connected to any floating point such that BOTH power supply output terminals are within ± 500 V. of power supply chassis ground.

EXTERNAL SENSING: When it is desired to regulate the voltage at some point remote from the OUTPUT terminals of the supply, the sense switch should be switched to EXT. and leads (preferably twisted pair) run to the desired point.

CAUTION: CARE SHOULD BE EXERCISED TO BE SURE THAT THE POSITIVE AND NEGATIVE LEADS ARE CONNECTED TO THE CORRESPONDING OUTPUT POLARITIES, OTHERWISE DAMAGE TO THE SUPPLY MAY RESULT.

If the leads are more than a few feet in length, it may be desirable to put a large electrolytic capacitor across the load to decrease the source impedance at the higher frequencies. Both the current and sense leads should be of heavy wire (number 16 or larger) and twisted. Lead resistance in the sense leads can approach 1 ohm (250 feet of number 16 wire) without appreciably degrading regulation specifications. However, pick-up may become a problem at these distances particularly if unshielded wire is used.

INTERNAL VOLTAGE CONTROL: With the OUTPUT SELECT switch set to VAR and the CONST. I./CONST. V. switch set to CONST. V. the output voltage will be determined by the setting of the thumb-wheel switches and by the range position of the CONST. I./CONST. V. switch. With this switch in the X10 position, the output voltage range is zero to 60 volts. In the X1 position, the range of output voltage is zero to 6 volts D.C. With the OUTPUT SELECT switch in the F.S. position, the output will be 60 volts, and 6 volts respectively with the CONST.I./CONST. V. switch in the X10 and X1 position. The resolution obtainable with the thumb-wheel switches is one part 10^5 of F.S. at any setting. The use of the Vernier increases the overall resolution to one part in 10^7.

REMOTE PROGRAMMING: When it is desirable to control the output voltage externally, the OUTPUT SELECT switch should be turned to EXT. and a 6K voltage divider should be connected to terminals A, B & C, the tap being connected to terminal A (See Fig. 3, Section 7). In this mode of operation the thumb-wheel switches have no effect on the output voltage of the power supply and the reading on the switch dials is not related to the voltage appearing at the OUTPUT terminals. The external control feature provides a means of setting a series of output voltages to any desired degree of accuracy commensurate with component tolerance and measuring instrument accuracy. By means of an appropriately selected divider resistor, any output voltage between zero and full scale may be obtained from the supply; (the full scale value obtained will be the same as that which would be obtained on internal control with the CONST. I./CONST. V. switch in the same position). The ratio of the output voltage so obtained to the full scale voltage will be equal to the ratio of the resistance between terminals A and B to the total resistance of the divider.

NOTE: Accuracy requirements on the 6K remote voltage dividing resistor: In the case of remote programming of all output ranges except the 60 volt full scale range, if the total resistance of the divider differs from the 6K total resistance of the Kelvin-Varley divider built into the supply by more than about 0.05%, the full scale output obtained in this way may differ by more than .01% from the absolute value. This can be corrected either by "padding" the external divider resistor or by changing the internal calibration adjustment in the power supply. In the latter case the result will be that the power supply will be out of calibration on all ranges except the 60 volt full scale range when on internal control. In the case of the 60 volt full scale range, the total resistance of the external divider resistor must be within about 1% of 6K if the calibration and line regulation characteristics of the supply are not to be degraded.

With the VOLTAGE CONTROL switch in the EXT. position, the output may be programmed by a variable voltage source connected with the POSITIVE to terminal B and the NEGATIVE to terminal A (See Fig.2, Section 7). The output of the power supply will be approximately 6.5 volts for each volt input when the X10 range is used. On X1 range, the output will be approximately one volt for each volt input. These are high impedance terminals (when the power supply is on) and no appreciable current is drawn from the external source (approximately 1 millimicroamp from a standard cell). When using this mode of operation care should be exercised that:

1. The polarity of the control voltage is as specified above.
2. The magnitude of the control voltage is such as not to produce a power supply output in excess of either 60 or 6 volts depending on the range used. Application of excessively high control voltage could result in damage to the supply.

Furthermore, it should be clearly understood that this power supply cannot be used in this mode as a power amplifier with any appreciable frequency response. The maximum rate of change of output voltage is about 10 volts per second which sets an absolute upper frequency limit for such use. If the control voltage moves from one quiescent state to another at a rate greater than that which would produce a change in output voltage at the maximum rate given above, the power supply will go into an out-of-regulation condition with the warning indicator lit until the new quiescent state

is reached. During the period when the out-of-regulation light is lit, the ripple in the output of the supply will be somewhat higher than normal. However, such operation WILL NOT damage the supply or produce transient overshoots in its output.

With external control the stability of the output will be determined either by the stability specifications of the power supply itself, or the stability of the control voltage, whichever is the less stable.

CONSTANT CURRENT OPERATION

With the CONST.I/CONST.V. switch set to CONST.I., this power supply becomes a constant current source maintaining regulation and stability characteristics as outlined in the specifications. In this mode of operation the digital dials read directly in milliamps. With the OUTPUT SELECT switch set to VAR, and with the CONST.I./CONST.V. switch set in the CONST.I. X1K position, the output current may be varied between zero and 2.0000 amps by means of the thumb-wheel switches. In the CONST. I. X100 and CONST. I. X10 positions respectively, the output current may be varied from zero to 600 milliamps and zero to 60 milliamps. The resolution of the thumb-wheel switch setting is one part in 10^5 of full scale at any setting. The use of the vernier extends the resolution to one part in 10^7.

In the CONST.I. X1K range the maximum current available is 2 amps, which is a limit imposed on the power supply by the overload circuit, as described in section 6 of this manual. (As the output current setting is increased, at some setting greater than 2.0000, the out-of-regulation light will come on indicating that the supply is current limiting. At all higher settings, and, in particular if the OUTPUT SELECT switch is set at "F.S.", an out-of-regulation indication will be obtained.

To obtain the 2 amp output, set the OUTPUT SELECT switch to VAR., the Kelvin-Varley divider to 1.9999 and the vernier fully clockwise. With the vernier set fully counterclockwise the thumb-wheel switches should be set to 2.0000.

In the CONST. I. X100 range and the OUTPUT SELECT switch set in the F.S. position, the full scale output is 600 milliamps.

In the CONST. I. X10 range and the OUTPUT SELECT switch in the F.S. position 60 milliamps of full scale output is obtained. When the OUTPUT SELECT switch is set to 0, the output of the power supply is zero.

The output current may be remotely controlled from zero to the full scale value appropriate to the setting of the CONST. I./CONST. V. switch by means of an external 6K voltage divider connected to the external control

terminals of the power supply. The ratio of the output current so obtained to the full scale current will be equal to the ratio of the resistance between A and B to the total resistance of the divider. The remarks as to the requirements on the 6K resistor given in the note in the remote voltage programming section apply here also.

The output current may also be set by an externally applied voltage. In the X1K range, an output of approximately one amp is obtained for each volt input. In the remaining two ranges the output current per one volt input is proportionately smaller. This external control voltage should be connected to the supply as outlined in the section on remote voltage programming.

With the external control, the stability of the output current will be determined either by the stability of the power supply itself, or the stability of the control element, whichever is the less stable.

OUT-OF-REGULATION INDICATOR: The OUT-OF-REGULATION indicator lights whenever the output differs from the current setting, thereby indicating an unregulated condition.

NOTE: In the constant current mode this power supply can be operated with the output floating or with the negative output terminal grounded. IT SHOULD NOT BE OPERATED WITH THE POSITIVE OUTPUT TERMINAL GROUNDED.

5. ADJUSTMENT AND CALIBRATION

This power supply has been carefully adjusted and calibrated prior to shipment. It should not require adjustment for many months. In the event that adjustment is felt to be necessary, it is advisable that the entire procedure given below be followed in the order given.

In order to properly adjust and calibrate this power supply the following equipment is needed:

1. A differential oscilloscope of at least 200 microvolts per cm. sensitivity (ex. Tektronix Type 502.)
2. A voltage measuring device sensitive to a voltage change of 20 microvolts at voltages between zero and 60V (a second stable power supply such as PAR type TC-100.2R plus a sensitive D.C. voltmeter such as the Hewlett Packard Model 425A makes a satisfactory arrangement).
3. An absolute voltage standard, able to measure 60V and 6V to an accuracy of 0.01%.
4. Precision shunt resistors for measuring current (see pages 26 through 28).
5. A resistor, variable between 0 and 100 ohms, capable of carrying 2.5 amps at any setting in this range.
6. An accurate "multi tester" such as the AVO Model 8.
7. A variable ratio autotransformer (ex. General Radio "Variac") of at least 5A capacity.

If such equipment is NOT available, and it is suspected that the power supply requires adjustment it should be returned to the factory.

CAUTION: This power supply is adequately protected from short circuit and overload as far as the external terminals are concerned. However, short circuits between points in the internal wiring can cause extensive damage to semiconductors. EXTREME CARE should be taken that metallic objects (tools, test leads, etc.) are not dropped into the internal wiring, and that wiring terminals are not inadvertently shorted together by clips, screwdriver shanks, etc.

NOTE:

1. In order to make the adjustments described below, the top and back covers must be removed from the unit.

2. Component Numbering System:

Components having R, C, Q, D etc. numbers lying in the range 0 to 99 are located on the chassis or one of the two printed circuit boards (OV-0373 or CC-0345A) which are mechanically attached to it and will be found on schematic diagram 0678-C-SD.

Components bearing R, C, Q, D etc. numbers in the ranges 100 to 199, 200 to 299, 300 to 399, respectively are located on the:

"Wideband Amplifier"(schematic 1485-C-SD, board #0360-D-ESA)

"Chopper Amplifier" (schematic #0048-C-SD, board #0377-D-ESA)

"Power Section" (schematic #0042-C-SD, board #0376-D-ESA)

3. For location of various controls referred to in the following, see Figure 5, Section 7.

4. Avoid removing or replacing boards with the instrument power turned on since damage may result.

PRE-REGULATION ADJUSTMENT: The "pass" or "series regulator" transistor (Q6) carries the full output current from the supply. In order to control the dissipation of this transistor the pre-regulation circuit (shown in Figure 6, Section 7) is employed. (For an explanation of the operation of this circuit see Section 6 of this manual). This pre-regulator maintains the voltage between the collector of Q4 and the emitter of Q6 between 10 and 14V at all output voltages and currents. This limits the maximum dissipation of Q6 to less than 14W under the worst output condition (2A near 0 volts). To set this voltage, set the output voltage to 60V, connect a voltmeter from the negative terminal of the panel meter (gray wire) to the front panel NEGATIVE OUTPUT terminal. Connect a load resistor to the OUTPUT terminals and adjust for 2 Amps output current. Adjust R307 to make the voltmeter read 11 $\pm$ 1 volts.

REFERENCE VOLTAGE SUPPLY CURRENT ADJUSTMENT: Q1 and associated circuitry consititute a simple constant current supply for the zener diode voltage reference. The regulation of this supply is not perfect, and if its output current were simply to be passed through a zener diode, and the voltage across it were then used as the reference voltage for the main power supply, the resulting reference voltage would change as the collector current of Q_1 changed due to the finite impedance of the zener diode. For this reason the reference zener diode (D_{31}) is placed in a bridge consisting of D_{31}, R_{33}, R_9 and R_{10}, the reference voltage being derived from this bridge rather than directly from the zener diode. If the ratio of R_{10} to the dynamic impedance

of the zener diode is equal to the ratio of R_9 to R_{33} than the reference voltage derived from the bridge will be (to first order) independent of bridge current. The dynamic impedance of the zener diode is dependent on the current through it, increasing as the current decreases. Consequently, if R_{33} has been astutely chosen, there is some value of current within the range of R_5 for which the bridge will be in balance. If we start with R_5 set for a current lower than this and increase it to a value higher than that for which the bridge is in balance; at first the reference voltage will increase (because the impedance of the zener is too high); as we pass through the correct current value the voltage will be momentarily stationary; as we continue to increase the current the voltage will begin to fall (due to the zener diode impedance being too low). Therefore, by adjusting R_5 for maximum reference voltage we adjust the zener diode impedance so as to balance the bridge. With the power supply output set at any convenient value between 0 and 60V, connect a d c voltmeter which can detect changes of 1 millivolt at this voltage to the output. Adjust R_5 so that this voltage is a maximum.

MAXIMUM CURRENT ADJUSTMENT: This adjustment sets the output current level at which the current limiting circuit takes effect. Connect a variable load resistor to the OUTPUT terminals in series with an ammeter (ex. AVO on 2.5A scale). Connect a differential oscilloscope to the OUTPUT terminals as follows: one input to the POSITIVE OUTPUT terminal, the other to the NEGATIVE OUTPUT terminal. Connect the scope chassis ground to the power supply GROUND terminal. Connect the POSITIVE OUTPUT terminal to ground. Increase the scope gain until ripple is visible. By reducing the resistance of the load, increase the output current to 2A and beyond until the ripple is seen to increase. Adjust R_{35} until this occurs at 2.1A. Reduce the resistance of the load resistor to zero. The current will increase but should not exceed 2.4A even under short circuit. If it does, the overload circuit is malfunctioning and must be repaired. (See Section for a description of the operation of this circuit).

WIDEBAND AMPLIFIER DC BALANCE ADJUSTMENT: (See Schematic diagram 1485-C-SD). The input stage of this amplifier is a matched pair of transistors (Q101A and B) operating as a differential amplifier. The d c balance adjustment (R109) enables the output of this stage to be adjusted to produce voltage within the specified range at the output terminals of the supply when the input

voltage to this stage is zero.

CAUTION:

BEFORE OPERATING THE UNIT WITH THE "AC AMPLIFIER" BOARD REMOVED, OR WITH D103 OR D104 SHORTED, MAKE SURE THAT THA "RANGE" SWITCH IS IN THE VOLTS X10 POSITION. IF THIS IS NOT DONE R_{46} MAY BE DAMAGED, AS IN EITHER CASE THE OUTPUT VOLTAGE MAY RISE ABOVE 100 V., RESULTING IN EXCESSIVE DISSIPATION IN R46.

To make this adjustment, it is necessary to short-circuit the bases of Q101 A and B after first turning off the supply. This is most easily done by clipping or tacking a jumper across diode D101 or D102 (located on the left-hand side of the board near the connector). Connect the multi-tester, set to a range of at least 60 volts d c, across the output terminals of the supply and turn on the supply. The meter will read either below zero or several volts above 60 volts. Adjust R109 (nearest to the center of the board) until the voltmeter is reading on scale and nearly stationary. (Due to the high loop gain of the amplifier it is virtually impossible to get a completely stationary reading). Turn off the supply and remove the jumper.

WIDEBAND AMPLIFIER RIPPLE ADJUSTMENT: The input to the wideband amplifier is provided by the output of the chopper amplifier. Because of the modulation and demodulation process in this latter amplifier, its output contains a ripple component at twice line frequency. Consequently, if the chopper amplifier were required to provide differential base current to the wideband amplifier input stage, a significant amount of 120 cycle ripple would be present at the output of the supply. The purpose of the ripple adjustment,R105, is to balance the steady-state base currents in Q101A and B so that the chopper is not required to deliver any quiescent current.

To make this adjustment set the OUTPUT SELECT switch to zero, turn on the supply, and connect the oscilloscope (set to most sensitive a c range) and the d c microvoltmeter to the output terminals. Adjust R105 to obtain an output as close to zero as possible. The amplitude of the ripple at the output goes through a broad minimum as the d c output passes through zero, and R105 may be adjusted for the best compromise between d c output and minimum ripple, as long as the residual output does not exceed ±100 microvolts d c and the ripple does not exceed 200 microvolts peak-to-peak.

If the residual output and ripple cannot be brought within these specifications, trouble beyond that which can be corrected by a simple adjustment is indicated and the unit should be returned to the factory for service.

Zero Voltage Line Regulation: At this point is is necessary to check the line regulation of the power supply at zero output voltage. With the power supply plugged into the variable transformer, set the OUTPUT SELECT switch to zero and connect the d c microvoltmeter to the output terminals. The positive terminal should be grounded. With the microvoltmeter set to 100 microvolts full scale, vary the line voltage up and down about 10% (being careful to remain between 105 and 125 volts at all times). The steady-state change in the voltmeter for a 10% line voltage change should not exceed 20 microvolts. A small adjustment of the Ripple potentiometer R105 may be required to meet this specification; however, the effect upon the residual d c output voltage and ripple amplitude must be observed to insure that their specifications are not exceeded (refer to paragraph 4 above).

REFERENCE VOLTAGE SUPPLY: Line voltage compensation adjustment: (see chassis wiring schematic 0678-C-SD). Q_1 and its associated components make up a constant current supply for the zener reference diode. The output current (collector current Q_1) is determined by the drop across D_{29} and D_{30}, the base-emitter voltage of Q_1, and R_5 plus R_6. D_{30} compensates for changes in the base-emitter voltage of Q_1 with temperature. As the line voltage changes, the voltage across the filter capacitor (C_{23}) changes, and as a result the current through D_{29} and D_{30} changes. Because of their finite impedance the base voltage of Q_1 will also change slightly. This would result in a change in the collector current of Q_1. The network R_3 and R_4 can be adjusted so as to change the current in R_5 plus R_6 and hence the emitter voltage of Q_1 by just enough to compensate for the change in base voltage. Set the power supply voltage to 60 volts and connect a sensitive D.C. meter capable of detecting ±20 microvolt changes at this voltage to its output. With the power supply connected to a variable line voltage source, vary the line voltage in ± 10% steps (being careful always to stay within the range of 105 to 125V A.C.). Adjust R_4 until the change in output voltage under thse conditions is a minimum.

CALIBRATION: VOLTAGE MODE:

60 VOLT RANGE: The full scale voltage obtainable from the power supply in the 60 volt range is set by R43. To set this (after allowing the supply at least a one hour warm-up period) set the CONST.I./CONST.V. switch to CONST.V. X10 and the OUTPUT SELECT switch at F.S. Measure the output voltage

R43 LOCATED SO THAT BOTTOM PANEL MUST BE REMOVED BEFORE ADJUSTMENT

of the supply with a voltage standardizing arrangement capable of measuring 60 volts to 0.01% accuracy. By adjusting R37, set the output of the supply to 60 volts as closely as possible.

CALIBRATION: CURRENT MODE:

2 AMP RANGE: The full scale current available from the supply in the 2 amp range is set by R50. To set this (after allowing the supply at least a one hour warm-up period), connect a precision resistor of 0.01% accuracy (or better), across the output terminals of the supply. The range of usable values of this resistor is determined by the following factors:

USE L+N SHUNT BOX E038

a) Since it must conduct 2 amps of current, and the maximum compliance voltage is 60 volts, the upper limit of the resistance is 30 ohms.

b) The lower limit of the resistance value depends on the precision of the apparatus used to measure the voltage drop across this resistor caused by 2 amps of current. This voltage must be measured to at least 0.01% of the absolute value.

c) This resistor, whatever its value within the limits outlined above, must maintain the 0.01% accuracy with 2 amps flowing through it.

CONNECT THE NEGATIVE OUTPUT OF THE SUPPLY TO THE CHASSIS GROUND TERMINAL OF THE SUPPLY. Set the CONST.I/CONST.V. switch in the CONST.I. X1K position, the output select switch at VAR, and the thumb-wheel switches to 2.0000. The vernier should be set at 0 (fully counterclockwise). Since under these conditions the supply should put out 2 amps , the voltage measured directly across the resistor should be 2R volts, where R is the resistance in ohms. Measure this voltage with a voltage standardizing arrangement good to 0.01% or better and adjust R50 to make it 2R volts as closely as possible.

600 MILLIAMP RANGE: The full scale current available from the supply in the 600 milliamp range is set by R53. To set this, connect a precision resistor of 0.01% accuracy (or better), across the output terminals of the supply. The resistor used to calibrate the 2 amp range may also be used here provided the voltage drop across it with 600 ma. flowing through it it not too low to measure within 0.01% accuracy. Set the CONST.I/CONST.V. switch in the CONST.I. X100 position and the OUTPUT SELECT switch in the F.S. position. Since the power supply should now put out 600 milliamps the voltage across the resistor should be 0.6R volts. Measure this voltage with a voltage standardizing arrangement good to 0.01% or better and adjust R53 to make it 0.6R volts as closely as possible.

E3141 USING SR1010 100Ω BOX in parallel

MAX CURRENT FOR 10 RESISTORS OF 100Ω/STEP IN PARALLEL = 710ma

60 MILLIAMP RANGE: The full scale value of current for this range depends on the setting of R56. Set the CONST.I./CONST.V. switch to CONST.I. X10 position. The full scale current available is now 60 ma. The resistor connected to the output whose drop will now be measured with 60 ma. flowing through it should be in the order of 100 ohms. Its value must be known within 0.01% and it must stay within this tolerance at 60 ma. Measure the voltage drop across this resistor to 0.01% or better and adjust R56 to make this voltage equal to 0.06R.

100Ω SR1010 in series-pa

This completes the adjustment and calibration procedure.

6. CIRCUIT DESCRIPTION

Basically, this power supply operates by comparing a fraction of the voltage appearing at its output with the voltage developed by a stable reference supply. The difference between these two voltages is amplified and applied to a control transistor which changes the output voltage in such a way as to minimize the difference. Thus the output voltage is determined by the condition that: (output voltage) X (ratio of output voltage divider) = reference voltage. The output voltage is varied, changing the reference voltage, by means of a 5 digit, decade Kelvin-Varley voltage divider followed by a continuously variable vernier. A brief description of the operation of the various circuits in the supply follows:

An important feature of this power supply is its silicon controlled rectifier pre-regulator circuit. In order for the supply to be able to deliver 60 volts it is necessary for the main rectifier to provide a DC output somewhat in excess of this. The main rectifier circuit actually used is capable of putting out approximately 80 volts DC at 2 amperes. If a simple regulating circuit, circuit consisting only of a pass transistor arrangement were to be used then, at low output voltages (i.e. approximately zero), the drop across the pass transistor would have to be about 80 volts. This would mean that at full load current (2 amp) the transistor would be dissipating approximately 160 watts. To get around this problem a pre-regulating circuit is incorporated in the TC-602CR. The function of this pre-regulating circuit is to control the average DC voltage across the main filter capacitor in such a way as to maintain the voltage drop across the series regulating elements between 10 and 14 volts under all conditions of output voltage and current. As a result, under worse case operation (full load current near zero volts) the power dissipated by the pass transistor is less than 14 watts.

The output regulator is controlled by a feedback amplifier (A1, A2 and A3 in Figure 4, Section 7) which is essentially a chopper-stabilized operational amplifier. The capacitive feedback provided by C101 and the parallel combination of C14, C15, and C16 has the effect of rolling-off the response of this amplifier at a steady 6 db per octave rate out to a frequency beyond which the loop gain has fallen below unity. This sort of open loop transfer

function results in freedom from loop oscillations and well controlled transient response.

For the discussion to follow refer to the chassis wiring schematic DWG. No. 0678-D-SD-A. The output voltage on the 60 volt range is sampled by the divider network consisting of R43, R44, R45, R46. The resistors in this divider are chosen on the 60 volt range so that when the power supply is putting out 60 volts, the junction between R44 and R45 is at -9.5 volts relative to the positive output terminal, and the junction between R45 and R46 is at -8.6 volts relative to this terminal. Since the range of full scale reference voltage is 8.6 volts to 9.5 volts (depending on the zener diode), this allows the power supply output on the 60 volt range to be set at 60 volts with the particular zener diode used. By adjusting R43 in the 6 volt range, R45 is connected directly across the output, which eliminates the output divider. At the same time the reference voltage across the Kelvin-Varley divider is reduced in the ratio 6:9.5 by means of a divider consisting of resistors R37, R38, R39 and R40. R37 is a variable resistor by means of which the reference voltage is adjusted to such a value as to result in 6 volt full scale output with the same setting of R43 as set for the 60 volt full scale output. This means that the adjustment of R43 made to compensate for the zener voltage, applies to the 6 volt range also.

The reference voltage is applied across the Kelvin-Varley divider. The output of this divider is compared to the output of the output voltage divider. The voltage regulating circuits operate so as to keep these two voltages the same. Consequently a change in the output of the Kelvin-Varley divider will produce a proportional change in the output of the power supply.

In the constant current mode X1K range, the output current is sampled by R48 in parallel with R49 and R50 and with the portion of the output divider R46, R45 and R43. The nominal value of R48 is chosen so that when 2 amps is being put out by the supply the voltage at the wiper of R43 is just the same as appears there when the supply puts out 2 volts in the 6 volt full scale voltage mode. Thus the setting of R43 to compensate the zener diode in the voltage mode, applies also in the current mode. R50 provides a small independent adjustment of the full scale value on the X1K current range. On the X100 current range, the output current is sampled by

R51 in parallel with R52 and R53 along with R46, R45 and R43. The value of R51 is chosen so that when the power supply is putting out 600 milliamps the voltage at the wiper of R43 is the same as appears there when the supply puts out 6 volts full scale. Again R53 provides a fine adjustment for this range.

The set of resistors to sample the current on the X10 range consists of R54, R55, and R56 along with R46, R45, and R43. As on the other current ranges the value of R54 is chosen so that when the output current is 60 ma., the voltage at the wiper of R43 is the same as if the power supply were putting out 6 volts full scale. R56 provides a fine adjustment for this range.

The fraction of the reference voltage set by the Kelvin-Varley divider, and a voltage proportional to output voltage/current are applied to the differential input of the photo-chopper amplifier (A1 shown in Figure 4, Section 7). Any difference in these two voltages is amplified by the combination of A1, A2 and A3 and applied as a control to the output regulator which changes the output voltage of the supply in such a way as to minimize the difference.

The reference voltage is obtained from the bridge consisting of R9, R_{33}, R_{10}, and D_{31}; with the bridge being driven by a regulated constant current supply. The purpose of the bridge network is to minimize changes in the reference voltage due to changes in the current produced by the constant current supply. If the ratio of R_9 to R_{33} is the same as that of R_{10} to the dynamic resistance of D_{31} then to first order, the voltage between points A and B (Figure 4, Section 7) is independent of the bridge supply current. Since the dynamic resistance of D_{31} is a function of its current the bridge may be balanced by varying the current supplied to it as described in Section 5. To insure maximum stability of the supply under changes in ambient temperature, R_{33} and the zener reference diode are mounted in a constant temperature oven.

The constant current supply mentioned above consists of Q_1 and associated components. The rectifier consisting of D25 through D28 develops a nominal voltage of 39 volts across C23. By means of D29, D30 and R7, a voltage of about 9 volts is established on the emitter of Q_1. As a result, a collector current of 18 to 25 ma may be established in Q_1, depending on R4. This constitutes the constant current for the bridge. D30 compensates for changes in the base emitter drop of Q_1 with temperature. As the line voltage changes, the voltage across C23 changes proportionally and as a result, due to the

finite impedance of D29 and D30, the base voltage of Q_1 will change, thus changing the current supplied to the bridge. R4 may be adjusted so that the series combination R3 and R4 will supply just enough change in emitter current to compensate this effect and to keep the collector current from changing.

The chopper amplifier (A1 in Figure 4) is contained on plug-in printed circuit board 0337-D-ESA (schematic diagram 0048-C-SD). The dc input signal is applied to pins 10 and 11 and converted to an ac signal by the action of photo resistors P201 through P204 which are illuminated by neon lamps B201, B205, B202 and B206 respectively. When a given photo resistor is illuminated its resistance is low (approximately 5 K ohms), when dark it is high (approximately 100 megohms). Therefore on one half cycle of the 60 cps line, the base of Q201 is connected to pin 11 and that of Q202 to pin 10. On the next half cycle the situation reverses. Thus P201 through P204 form a DPDT switch between pins 10 and 11 and the bases of Q201 and Q202 which is switched at a 60 cps rate. Any DC signal appearing between 10 and 11 is converted to a proportional 60 cps AC signal at the bases of Q201 and Q202. This AC voltage is amplified by the two stage differential amplifier consisting of Q201, Q202, Q203 and Q204. P205 through P208 form an exactly similar synchronous DPDT switch at the output, converting the amplified AC voltage into a proportional dc voltage which appears between pins 6 and 7.

Q205, Q206 and associated components serve to operate the out-of-regulation light, Q205 being biased in such a way that when the AC signal at the collector of Q203 reaches about 1 volt peak-to-peak, Q206 just begins to conduct. Since the out-of-regulation light is in the collector circuit of Q206, at this point it would just begin to glow.

Amplifier A2 and A3 of Figure 4 are contained on plug-in printed circuit board 1443 (Schematic diagram 1485-C-SD). A2 consists of Q101, Q102, Q103 and associated components. Two adjustments are provided in this circuit. R109 compensates for any difference in the base emitter voltages of Q102 and Q103. It is adjusted so that with zero input (D101 and D102 shorted) the feedback amplifier is in its linear range. R105 is adjusted to balance the quiescent base current required by Q101. Since this means this current does not have to be supplied by the somewhat ripply output of the chopper amplifier, this adjustment serves to minimize ripple in the output of the supply. A3 consists of Q104 and associated components. This stage is driven by A2 and in turn drives the output regulators (Q5 and Q6).

The power section (plug-in printed circuit board 0375-D-ESA, schematic diagram 0042-C-SD) provides regulated ± 18 volts DC for the wideband and chopper amplifier circuits. The -18 volt regulator consists of Q307, Q308, Q309, Q310, Q306 and associated components. It is referenced to the main power supply reference voltage. The +18 volt supply consists of Q303, Q302 and Q301 and associated components; it is referenced to the -18 volt supply. Both of these supplies are completely conventional in operation.

Figure 6, Section 7 is a schematic diagram of the pre-regulator section of the power supply. D9 through D12 constitute the main rectifier for the power supply. It will be seen that the main filter capacitor (C3) is connected to the rectifier output through the silicon controlled rectifier (Q2). The waveform of the full wave rectified output of the main rectifier is shown in Figure 6. The driving circuitry for Q2 is arranged in such a way that Q2 will be turned on some time during the shaded portion of each half cycle. It will be seen that the later in the half cycle Q2 is turned on. Once turned on, Q2 will remain on until the current through it drops to a value near zero, i.e. it will turn off somewhere near the end of the half cycle. It will remain off until provided with a new trigger pulse. The voltage across the series regulator circuitry is sensed by Q311. It will be seen from examining Figure 6 that the higher this voltage is, the greater will be the collector current of Q311. This collector current is obtained through the network consisting of R307 and R308. This network also supplies the base current of Q305. D8, D7, Q304 and associated components combine to produce the waveform at the collector of Q304 shown on Figure 6. It will be seen that this waveform produces a rapid increase in the base current of Q305 during the last half of each full wave rectified half cycle. The emitter current of Q305 will be determined by the sum of the DC current provided by R307 and R308 and the AC current provided via R311 from Q304. When this emitter current reaches a critical value, Q2 will turn on. It will be seen that the smaller the DC base current contributed to Q305 from R307 and R308, the later in the half cycle Q2 will come on. The more current Q311 draws the smaller will be the DC current available to Q305. Consequently, the higher the voltage across the series regulator, the later in the half cycle Q2 will fire. As a result, if the voltage across the series regulator attempts to increase, Q311 will draw more current, thus decreasing the quiescent base current of Q305 and making Q2 fire later in

the cycle hence, reducing the voltage across C3. The net result is to reduce the voltage across the series regulator. The network consisting of R301, D301, R305 and C301 plays a role only when the power supply is first turned on. At turn-on it takes some time for the plus and minus 18 volt regulated supplies to come to proper voltage and as a result the pre-regulator circuit does not function for some time after the supply is first turned on. As a result, it is possible that a large voltage could be developed across C3 at turn-on with possible damage to transistors in the series regulator. The previously mentioned network insures this will not happen since the -25 volt unregulated voltage appears almost instantaneously at turn-on and as a result no dc bias current will be available to Q305 until C301 charges to +18 volts through R301.

The current limiting circuitry shown on the chassis wiring schematic 0678-C-SD consists of D19, D17, Q3 and R25 through R28. The forward base current of Q5 is obtained from the collector of Q3 which is normally held in a saturated condition. The full output current flows through whichever one of R25 through R28 has been selected by the OUTPUT CURRENT switch. As the output increases, the drop across this resistor increases until at full current for the given switch position it reaches a value of 6 volts. As it is increases further, a point is reached at which D19 begins to conduct. Some of the current available to Q3 and hence to the base of Q5 now begins to flow through D19. As the current is increased further, a greater fraction of the current available to Q3 flows through D19, further reducing the base current available to Q5. As one attempts to increase the output current still further, a stable point is soon reached beyond which the output current cannot be further increased. This effectively limits the current available to the pass transistor (Q6). However, in the case of a suddenly applied short circuit at a time when the power supply was putting out a voltage near 60 volts, due to the rather slow action of the pre-regulator circuit, the entire 60 volts would appear across the series regulating circuitry for a few seconds until the pre-regulator recovered control. Under these conditions the power dissipated by Q6 would be excessive and Q6 could be damaged. Q4 and zener diode D21 prevent this from occuring. Q4 is normally held in a saturated condition by the current flowing into its base through R24. As the voltage drop between the base of Q4 and the emitter of Q6 approaches 24 volts (the value of which D21 begins to conduct) some of the base current available to Q4 begins to flow through D21. At this point Q4 begins to come out of saturation and as the voltage on the emitter of Q6 continues to drop, the

base of Q4 will follow along at a potential 24 volts higher. Thus the drop across the series regulating circuit is limited to a maximum of 24 volts even under transient conditions by the combination of D21 and Q4. Within a few seconds after the application of a short circuit the pre-regulating circuitry will recover control and the voltage drop across the series regulating circuitry will return to its normal value.

The output current metering is obtained by connecting the panel meter, which is actually a voltmeter reading 6 volts full scale, across whichever one of the resistors R25 through R28 is in use.

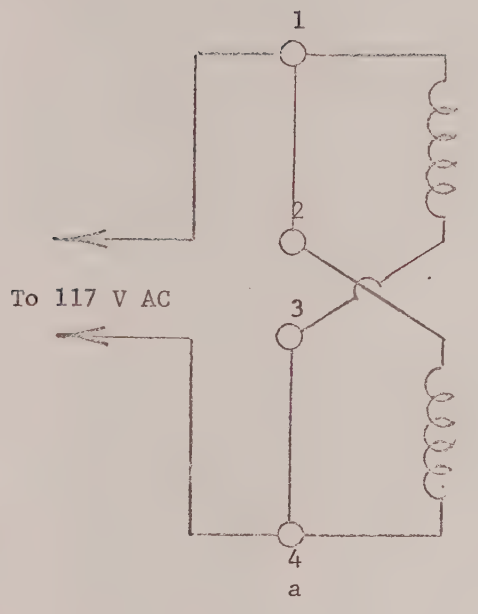
8. WARRANTY

Princeton Applied Research Corporation warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty are limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned prepaid to our factory for that purpose within ONE YEAR of delivery to the original purchaser. Instruments returned to the factory are accepted only when prior authorization has been given by an authorized representative of Princeton Applied Research Corporation.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control. (Tubes, semiconductors, choppers, and lamp bulbs are exempted from this Warranty).

Princeton Applied Research Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This Warranty is in lieu of, and excludes all other warranties or representations, expressed, implied or statutory, and all other obligations or liabilities of Princeton Applied Research Corporation including special or consequential damages, and no other source is authorized to assume for Princeton Applied Research Corporation any other liability.



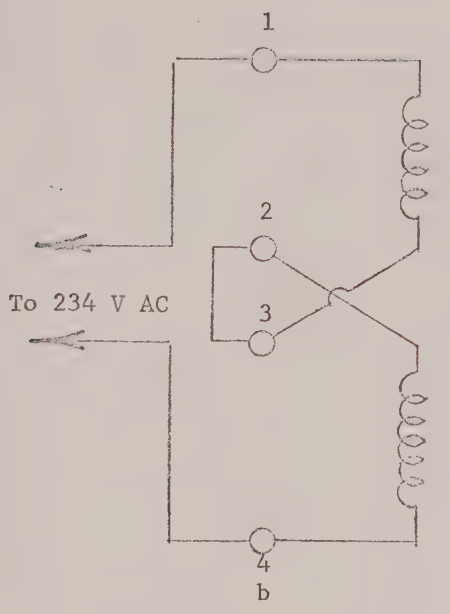


FIGURE 1

a) TRANSFORMER PRIMARY WINDING CONNECTED FOR OPERATION FROM 117 V AC POWER SOURCE.
b) TRANSFORMER PRIMARY WINDING CONNECTED FOR OPERATION FROM 234 V AC POWER SOURCE.

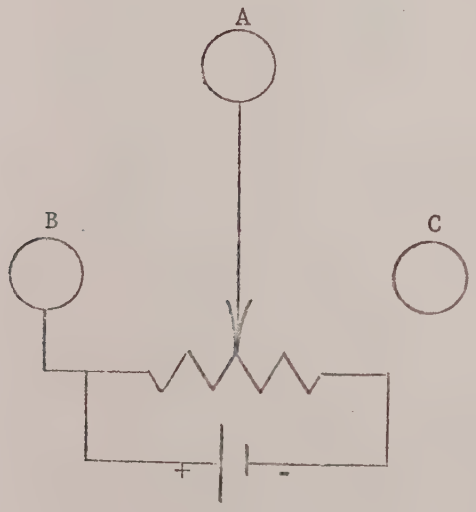


FIGURE 2

CONNECTION OF DC SOURCE FOR EXTERNAL PROGRAMMING OF THE OUTPUT VOLTAGE OR CURRENT

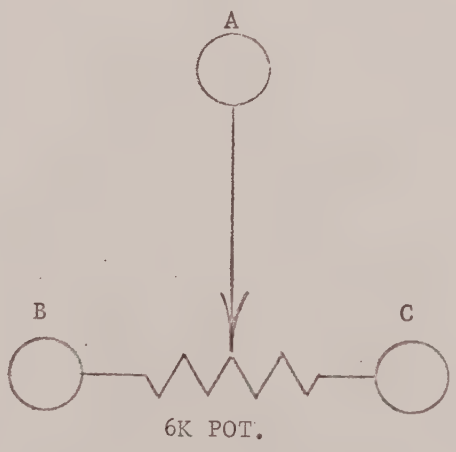


FIGURE 3

CONNECTION OF 6 K POTENTIOMETER FOR EXTERNAL PROGRAMMING OF THE OUTPUT VOLTAGE OR CURRENT.

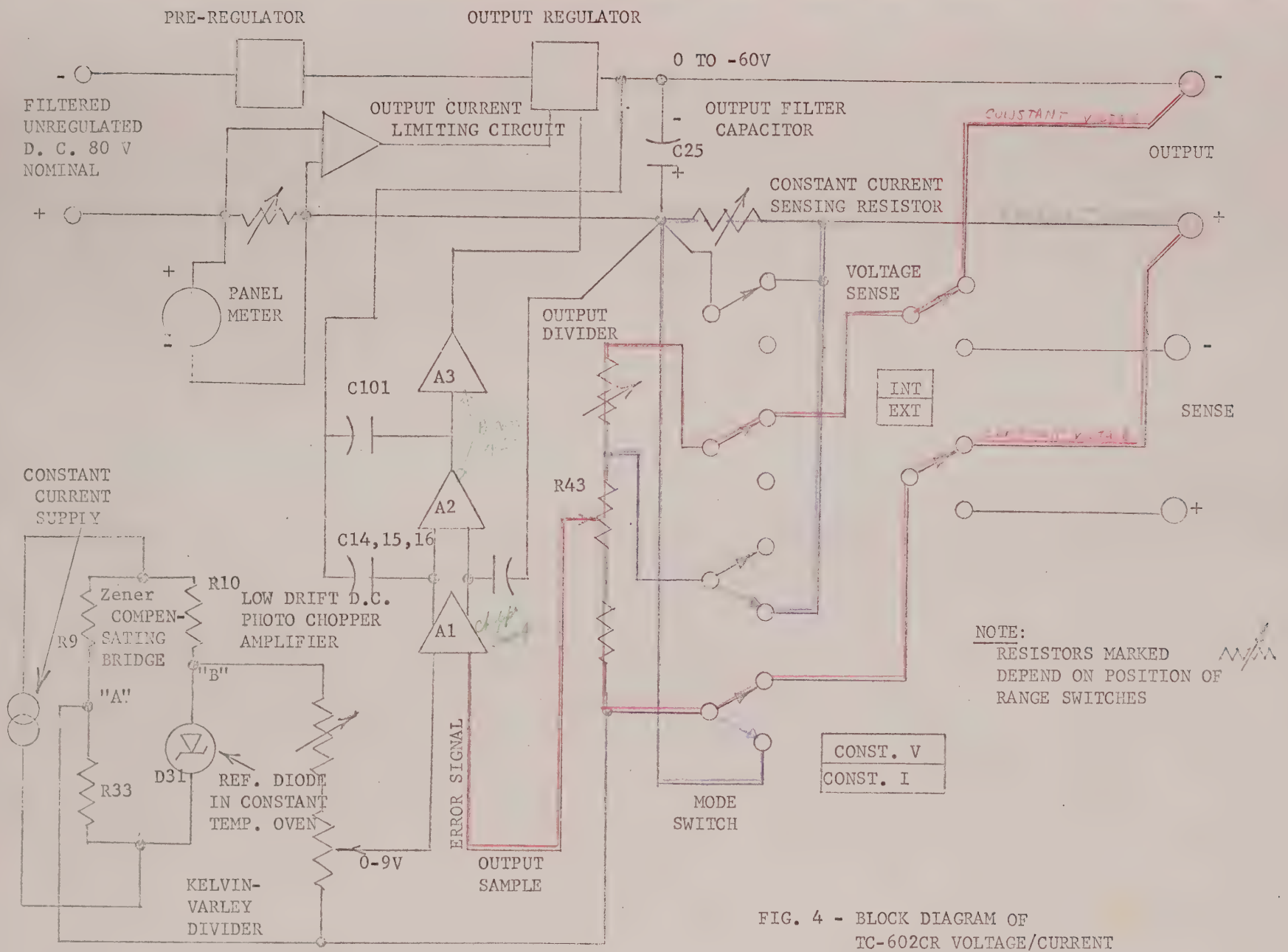


FIG. 4 - BLOCK DIAGRAM OF TC-602CR VOLTAGE/CURRENT REFERENCE SOURCE

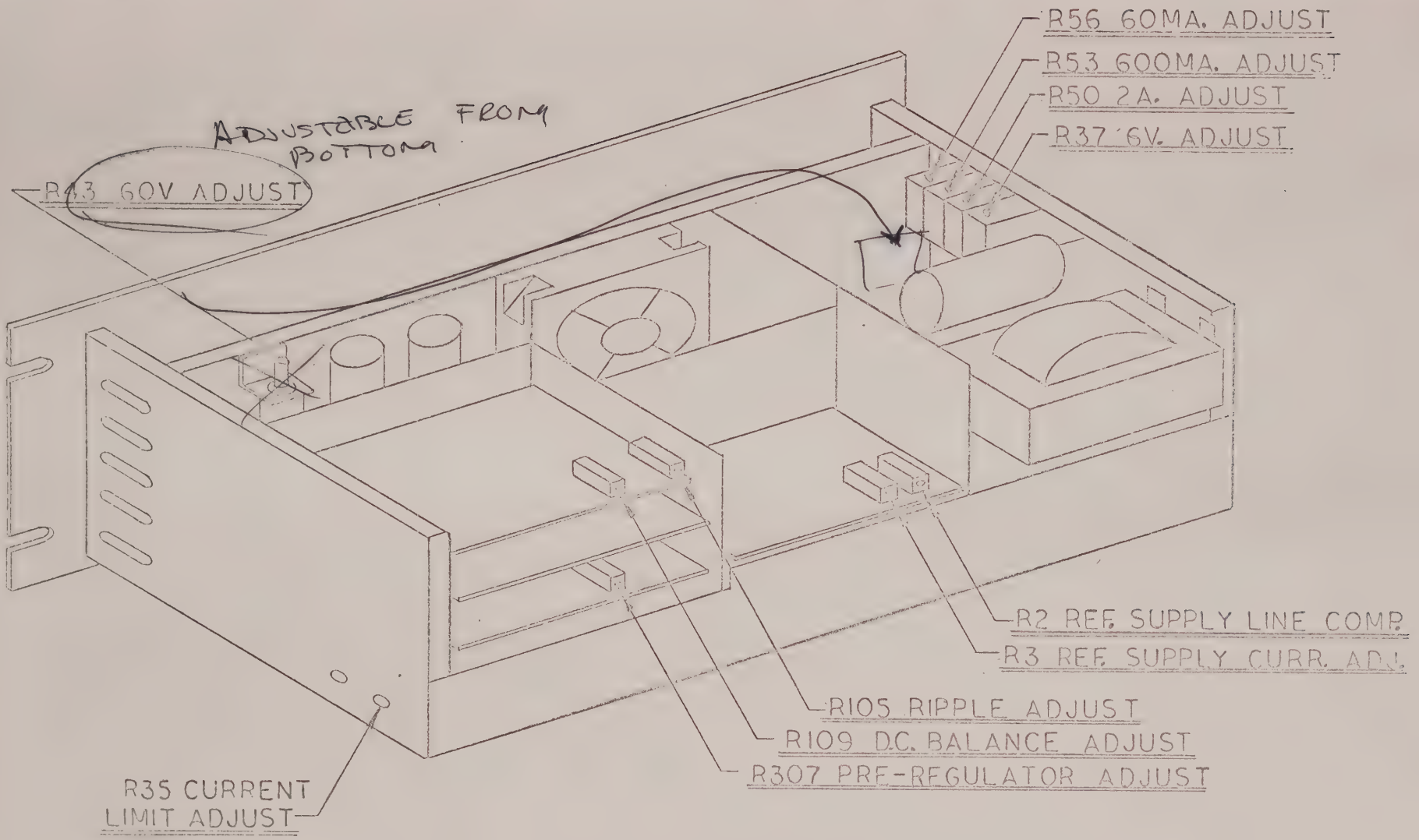
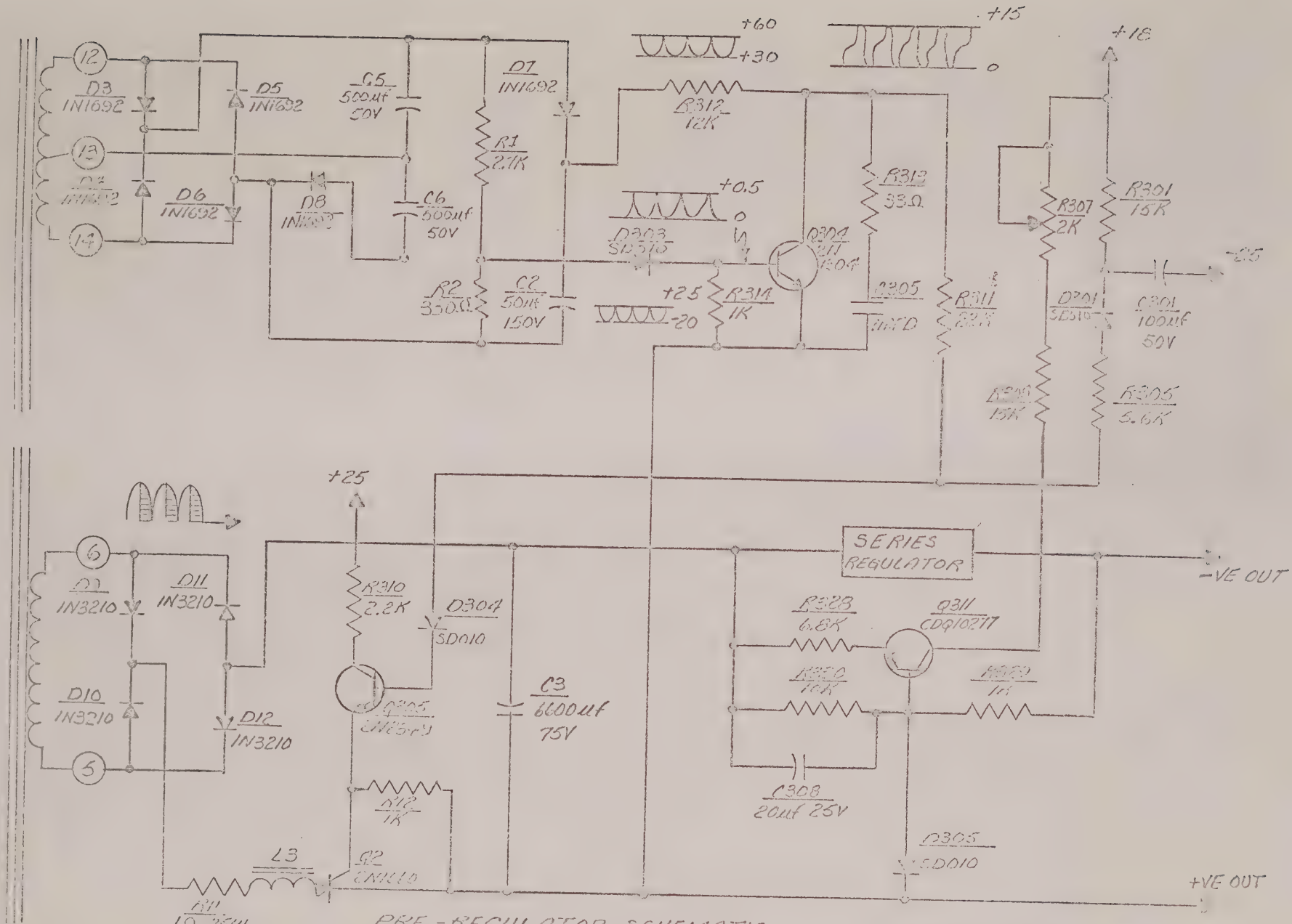


FIGURE 5

ADJUSTMENT LOCATIONS MODEL TC-602CR



PRE-REGULATOR SCHEMATIC

TC-602 CR

FIGURE 6

SALES OFFICES

PRINCETON APPLIED RESEARCH

DOMESTIC SALES OFFICES AND REPRESENTATIVES

(INTERNATIONAL OFFICES LISTED ON REVERSE SIDE)

MAIN OFFICE
PRINCETON APPLIED
RESEARCH CORP.
P.O. Box 565
Princeton, New Jersey 08540
Phone: (609) 924-6835

SHIPPING ADDRESS
PRINCETON APPLIED
RESEARCH CORP.
Rte. 518 E. of Rte. 206
Princeton, New Jersey

1. PRINCETON APPLIED
RESEARCH CORP.
17 Dunster Street
Cambridge, Mass. 02138
Phone: (617) 491-6800

2. PRINCETON APPLIED
RESEARCH CORP.
4922 St. Elmo Avenue
Bethesda, Md. 20014
Phone: (301) 652-0010

3. TECHNICAL ASSOCIATES, INC.
2319 East South Street
Orlando, Fla. 32803
Phone: (305) 424-5681

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Tel: 77-70-96 Telex: 841-528476

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Stresemannallee 61
West Germany
Tel: 62-60-16 Telex: 841-411243

PRINCETON APPLIED RESEARCH CORPORATION

POST OFFICE BOX 565
PRINCETON, N.J. 08540
TELEPHONE 609-924-6835
CABLE: PARCO

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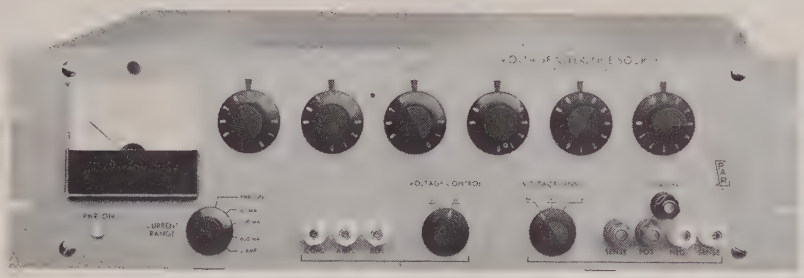
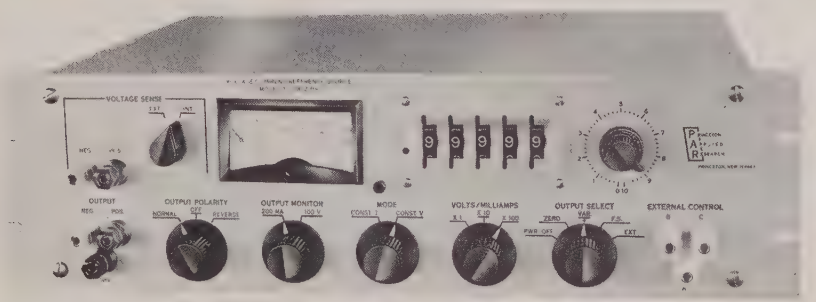
PRINCETON APPLIED RESEARCH

PRECISION INSTRUMENTS FOR RESEARCH



VOLTAGE/CURRENT REFERENCE SOURCES



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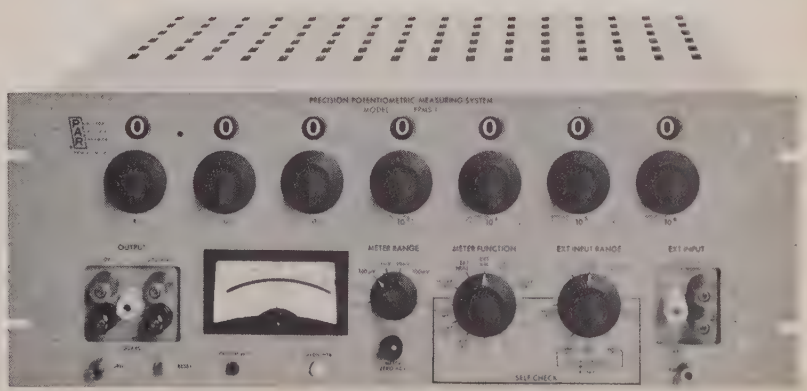

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P. O. BOX 565 • PRINCETON, NEW JERSEY 08540

TELEPHONE: 609-924-6835

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QUICK REFERENCE GUIDE TO PAR REFERENCE SOURCES

MODEL NO.	OUTPUTS CONST. V.	OUTPUTS CONST. I.	ACCURACY CONST. V.	ACCURACY CONST. I.	RESOLUTION CONST. V.	RESOLUTION CONST. I.	100 HOUR STABILITY CONST. V.	100 HOUR STABILITY CONST. I.	PRICE
TC-260R	0 to 60V @2A max.	0 to 2A @ 60V max. (Requires Ext. Resistors)	0.01%	0.01% ± Accuracy of Ext. Resistors	20μV	Determined by Ext. Resistors	.001%	.001% ± stability of external resistors	$1,250.
TC-100.2R	0 to 100V @200mA max.	0 to 100mA* @ 100V max.	0.01% of F.S.	0.02% of F.S.	1mV	1μA	.001%	.002%	$1,500.
TC-602CR	0 to 6V 0 to 60V @2A max.	0 to 60mA 0 to 600mA 0 to 2A @ 60V max.	0.01%	0.01%	1μV min.	10nA min.	.001%	.002%	$1,750.
TC-100.2AR	0 to 100V 0 to 10V 0 to 1V @200mA max.	0 to 100mA* 0 to 10mA 0 to 1mA @ 100V max.	0.005%	0.01%	10μV min.	10nA min.	.001%	.002%	$1,800.
TC-100.2BR	0 to 100V 0 to 10V 0 to 1V @200mA max.	0 to 100mA* 0 to 10mA 0 to 1mA @ 100V max.	0.005%	0.005%	100nV min.	100pA min.	.001%	.001%	$2,200.
SF-Series (Fixed)	Any fixed voltage to 100V @2 amps max.	Any fixed current to 2 amps @ 100V max.	Within setting resolution		Up to 1 ppm of adjustable range about nominal		.001%	.001%	By quotation only.
PPMS-1	Self-contained secondary standard for making highly-precise measurements of external resistance ratios or DC voltages to 1000 Volts.								

*Available to 200mA (at extra charge).

PAR VOLTAGE/CURRENT REFERENCE SOURCES FEATURE:

- ACCURATE DIGITAL OUTPUT SELECTORS
- COMPLETE SHORT CIRCUIT PROTECTION
- INTERNAL/REMOTE VOLTAGE SENSING
- INTERNAL/REMOTE OUTPUT CONTROL
- 0.0001% (1 PPM) LINE REGULATION
- 0.0001% LOAD REGULATION
- 5 PPM/°C TEMPERATURE COEFFICIENT (MAX.)
- TEMPERATURE CONTROLLED/STABILIZED REFERENCE
- 0.001% 100 HOUR VOLTAGE STABILITY
- EXTREMELY LOW RIPPLE AND NOISE
- LESS THAN 10 MICROHMS OUTPUT IMPEDANCE
- NO OVERSHOOTS DURING TURN-ON/OFF
- 25 MICROSECONDS RECOVERY TIME, NO RINGING
- COMPLETELY SOLID-STATE

GENERAL CHARACTERISTICS APPLICABLE TO ALL MODELS

GENERAL: This group of completely solid state power supplies provides extremely well-regulated voltage and current outputs, with a large number of built-in features which permit considerable operational flexibility in a variety of applications. Careful, conservative design has led to highly reliable and stable operation of these reference sources.

OUTPUT: Digital voltage and current selectors provide for accurate settings to within absolute accuracy specifications. The reference voltage is temperature stabilized and temperature controlled, insuring excellent short and long term stability over a wide temperature range.

ISOLATION:

CONSTANT VOLTAGE: Output is floating with respect to ground and supplies may be operated with either terminal grounded or as much as 500 VDC off ground. Leakage resistance from either terminal to ground is approximately 100 megohms.

CONSTANT CURRENT: In order to obtain stated performance, supplies must be operated with NEGATIVE terminal grounded (floating operation is also satisfactory for most applications.) Supplies may be out of specification when operated with positive terminal grounded.

OVERLOAD AND SHORT CIRCUIT PROTECTION: Output current will not exceed by more than 20% the full scale current under overload conditions. Prolonged short circuit operation will not damage the supplies, and normal output voltage is restored automatically upon removal of the load fault.

REMOTE CONTROL: Remote programming of the output voltage or current over the full operating range with a 10K potentiometer (6K on Models TC-260R and TC-602CR), or an external voltage source is available on variable output models.

REMOTE SENSING: Sensing terminals are provided to regulate the voltage at a remote point.

OUTPUT IMPEDANCE (at any load): In the constant voltage mode, internal impedance is less than 10 microhms at DC and less than 100 milliohms at 100 kHz (see graph.) It increases slowly with frequency and is almost completely temperature insensitive.

SURGES AND TRANSIENT RESPONSE: No voltage or current overshoots occur during turn-on or turn-off under all load conditions (see illustrations at right.) In the constant voltage mode of operation, recovery to within 10 millivolts of steady state voltage is obtained after application, or removal, of full load in less than 25 microseconds.

CHOPPER-STABILIZED AMPLIFIER: These power supplies utilize a unique chopper-stabilized amplifier with a DC open loop gain of 5×10^6, falling off no faster than 6 dB per octave to unity gain. This insures extremely low output impedance and fast transient response without ringing. Non-DC components in the output (ripple, hum, noise and spikes) are nonetheless maintained at an extremely low level under all load conditions.

VOLTAGE AND TEMPERATURE STABILITY: Extremely small drifts over a period of days are obtained by use of a temperature-controlled and temperature-stabilized reference and low-temperature-coefficient resistors.

OUT-OF-REGULATION INDICATOR: Indicator lights whenever output voltage or current is not being regulated in accordance with output setting.

INPUT VOLTAGE REQUIREMENTS: 105-125 or 210-250 volts, 50 or 60 Hz.

SIZE: 19"W x 5¼"H x 14"D.

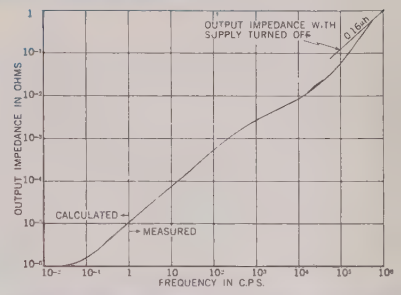
COOLING: Forced Air.

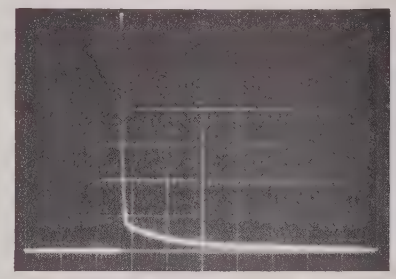
WEIGHT: Approximately 35 lbs.

WARRANTY: 1 year.

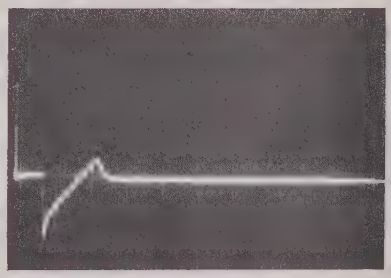
PRICE: Stated with each model, export prices approximately 5% higher, except Canada.

Specifications and Prices Subject to Change Without Notice

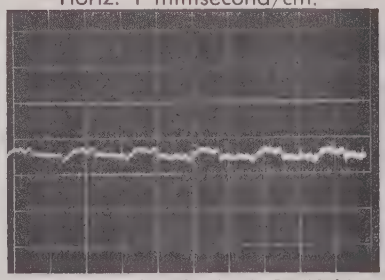




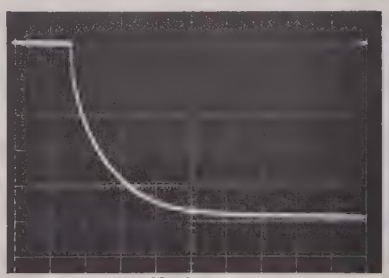
Transient response, no load to full load.
Vert. 10 millivolts/cm.
Horiz. 50 microseconds/cm.



Transient response, full load to no load.
Vert. 5 millivolts/cm.
Horiz. 1 millisecond/cm.



Output Ripple TC-100.2BR, 50 kHz Bandwidth
Vert. 100 μvolts/cm
Horiz. 10 milliseconds/cm



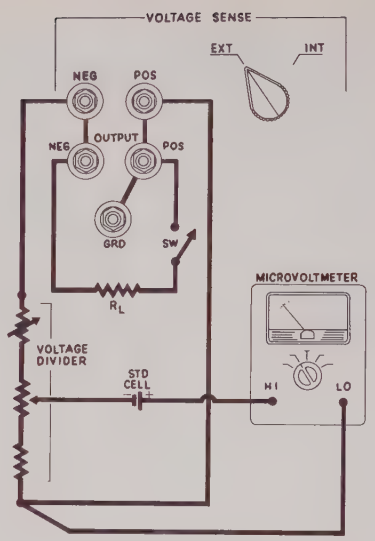
Turn-off characteristic.
Vert. 10 volts/cm.
Horiz. 0.1 second/cm.

SPECIFIED ACCURACY, STABILITY AND REGULATION VALUES ARE PRECISELY MEASURED UNDER CLOSELY-CONTROLLED CONDITIONS.

Typical Test Set-Ups are Shown Below.

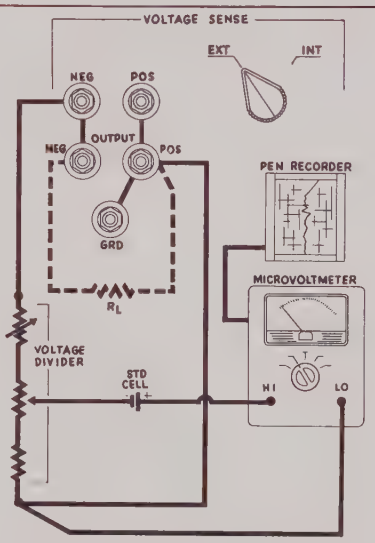
1. Load Regulation Measurements are made as follows:

The equipment set-up, as shown in the diagram, forms a bridge circuit with the microvoltmeter used to measure the null voltage. As the standard cell voltage remains constant with removal or addition of the load; all of the voltage variation appears across the terminals of the microvoltmeter. Provided that the voltage divider has a low temperature coefficient and that the ambient temperature is held relatively constant, fluctuations of a microvolt or less can be accurately measured.



2. Stability Measurements in the Constant Voltage Mode are made as follows:

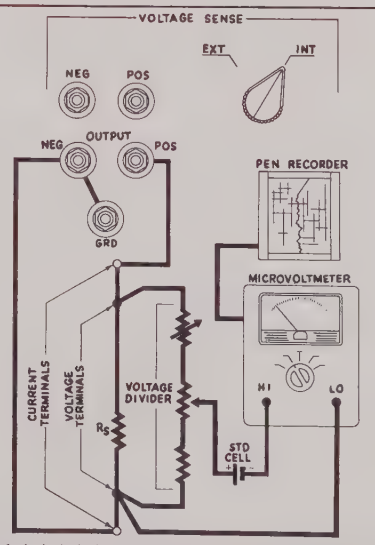
With the equipment set-up as shown in the diagram, addition of the load is optional as measurements can be made with no load, partial load, or full load. The microvoltmeter is again connected to function as a null meter. The recorder, driven by the microvoltmeter, is zeroed after the warm-up period. Thus, 100-hour or longer stability checks can be easily run, as the recorder will show any variation in the reference source output. Here again the voltage divider must have a low-temperature coefficient and ambient temperature must be closely controlled for repeatable, accurate results.



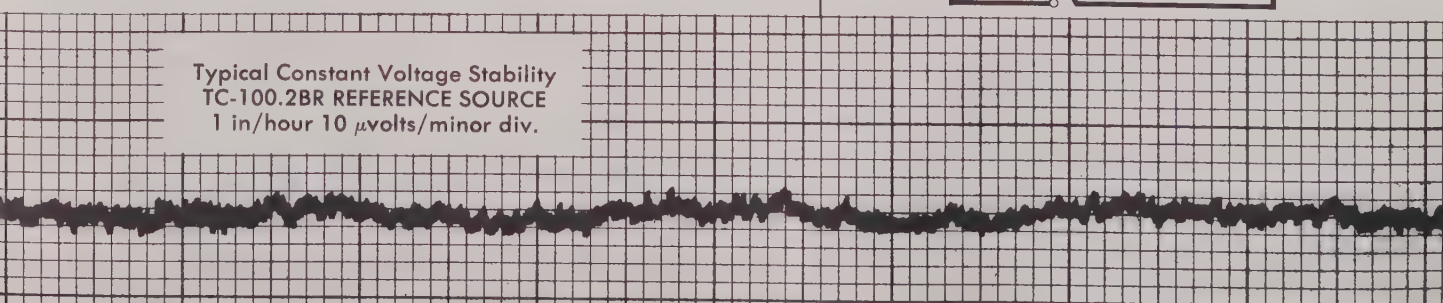
3. Stability Measurements in Constant Current Mode are made as follows:

With the equipment connected as shown in the diagram, the familiar bridge circuit with null meter is again obvious. As in the voltage measurement case, the recorder is zeroed after warm-up for long-term stability runs. The precautions of a low-temperature coefficient voltage divider and relatively stable ambient temperatures also apply in the constant current mode. One additional precaution must also be observed. While not always absolutely necessary, it is generally good practice to use a four-terminal resistor for the load. This separates the voltage measuring loop from the current connections to reduce IR inaccuracies.

Tests for other specified parameters are made in generally similar ways with the same basic set-ups.



Typical Constant Voltage Stability
TC-100.2BR REFERENCE SOURCE
1 in/hour 10 μvolts/minor div.



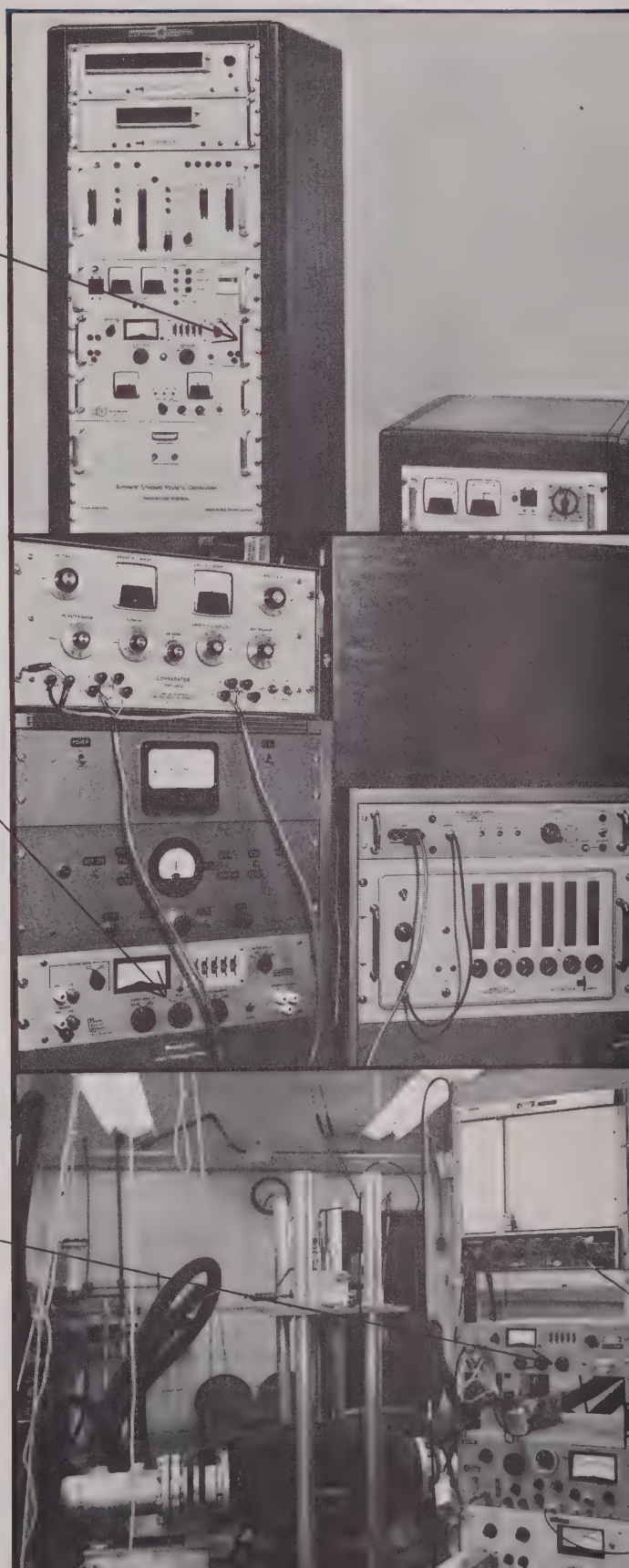
TYPICAL APPLICATIONS OF PAR VOLTAGE/CURRENT REFERENCE SOURCES

The accuracy, stability and reliability of PAR reference sources make them suitable for a wide range of applications. Some typical applications are shown below.

The Automatic Standard Magnetic Observatory (ASMOR) built by Varian Associates for the U. S. Coast & Geodetic Survey near Santa Cruz, California, incorporates a modified PAR TC-100.2AR Precision Voltage/Current Reference Source functioning as a precision constant-current source. The unit was selected for use in the ASMOR system to provide an extremely accurate, regulated current source for field-biasing Helmhotz coils. This was necessary to prevent perturbations in the constant-current power supply from causing spurious indications in the output.

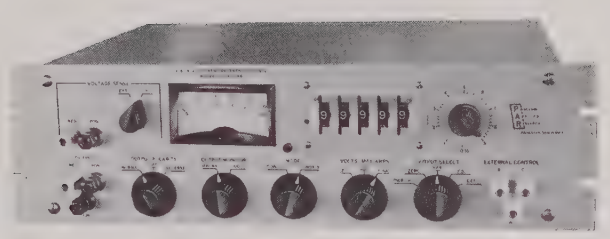
At the Department of Chemistry at Oklahoma State University, a PAR TC-100.2AR Precision Voltage/Current Reference Source is used as a constant-voltage source in the temperature measurement system and calibration instrumentation for a reaction calorimeter. The rapid transient response and the low output impedance of the PAR voltage source minimize transients during high-speed switching between the calorimeter heater and its associated dummy load.

At the National Magnet Laboratory at Massachusetts Institute of Technology, a PAR TC-602CR Power Supply has been used by a group from NASA's Electronic Research Center to provide a constant voltage, tunnel diode power supply. Typical experiments here have included the study of small oscillations (with amplitudes of the order of 20-50 microvolts) which occur when certain diodes are reverse biased in strong magnetic fields at low temperatures.

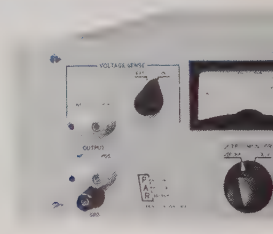


SPECIFICATIONS FOR 10

CONSISTING OF MODELS TC-10



MODEL TC-100.2BR



MO

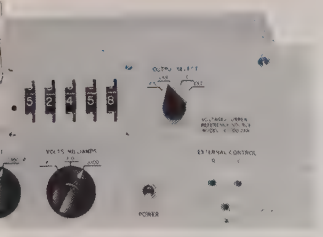
SPECIFICATIONS - MODEL TC-100.2BR AND MODEL TC-100.2AR

	Constant Voltage	Constant Current
OUTPUT VOLTAGE:	Zero to 100 volts	100 volts maximum
OUTPUT CURRENT:	200 mA maximum	Zero to 100 mA (available to 200 mA at extra charge)
OUTPUT CONTROL: Selectable in three ranges. Full scale output (1, 10, 100 volts or milliamps) obtained by front panel switch position. Polarity reverse switch on front panel of TC-100.2BR only.	TC-100.2BR 0 to 1.000000 volts 0 to 10.00000 volts 0 to 100.0000 volts TC-100.2AR 0 to 0.99999 volts 0 to 9.9999 volts 0 to 99.999 volts	TC-100.2BR 0 to 1.000000 mA 0 to 10.00000 mA 0 to 100.0000 mA TC-100.2AR 0 to 0.99999 mA 0 to 9.9999 mA 0 to 99.999 mA
LOAD REGULATION: (no load to full load) (zero to maximum resistance)	±.0001% or 2 μV (on 1 & 10 V ranges)	±0.0001% or 10 nA, whichever greater (on 1 & 10 mA ranges)
LINE REGULATION: (10% line voltage change)	±.0001% or 20 μV (on 100 V range)	±0.0001% or 100 nA whichever is greater (on 100 mA range)
ABSOLUTE ACCURACY:	±0.005% of setting ±10 μV (on 1 & 10 V ranges)	±0.005% of setting ±100 nA (.2BR) ±0.01% of setting ±100 nA (.2AR) (on 1 & 10 mA ranges)
	±0.005% of setting ±100 μV (on 100 V range)	±0.005% of setting ±1 μA (.2BR) ±0.01% of setting ±1 μA (.2AR) (on 100 mA range)
NOISE: (at any load) (combined ripple, hum, noise and spikes)	Less than 40 μV p-p (on 1 & 10 V ranges) Less than 100 μV p-p (on 100 V range)	Less than 100 nA p-p (on 1 & 10 mA ranges)* Less than 1 μA p-p (on 100 mA range)
SHORT TERM STABILITY: (At constant ambient temperature) Maximum 100 hour drift after 1 hour warm-up period	±0.001% ±2 μV (on 1 & 10 V ranges) ±0.001% ±20 μV (on 100 V range)	±0.001% or ±10 nA (.2BR) ±0.002% or ±20 nA (.2AR) (on 1 & 10 V ranges) ±0.001% ±100 nA (.2BR) ±0.002% ±200 nA (.2AR) (on 100 mA range)
LONG TERM STABILITY: (1 year)	±0.01% ±10 μV (on 1 & 10 V ranges) ±0.01% ±50 μV (on 100 V range)	±0.01% ±100 nA (on 1 & 10 mA ranges) ±0.01% ±1 μA (on 100 mA range)
TEMPERATURE STABILITY: (at controlled ambient temperatures from 15°C to 35°C)	Within 5 ppm/°C	Within 5ppm/°C
PRICE:	Model TC-100.2AR $1,800	Model TC-100.2BR $2,200

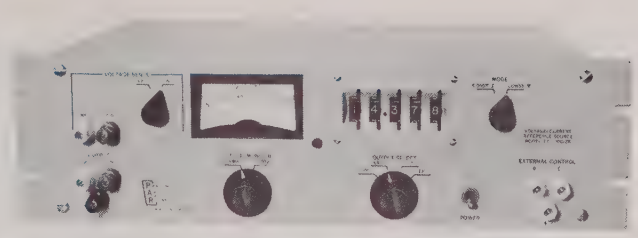
*With negative ground. Noise will increase to approximately 700 nanoamps p-p with positive ground.

) VOLT, 200 MA SERIES

2BR, TC-100.2AR AND TC-100.2R



TC-100.2AR



MODEL TC-100.2R

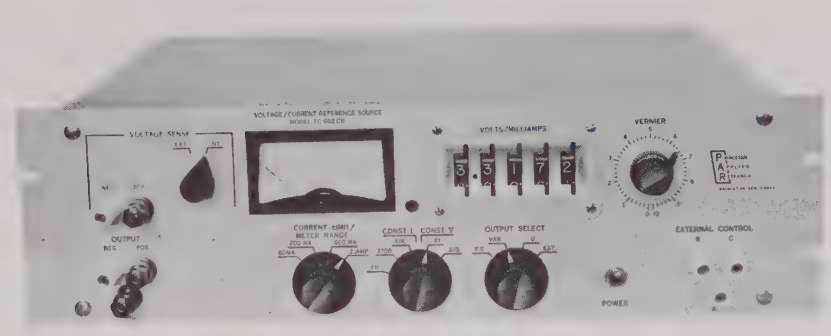
SPECIFICATIONS - MODEL TC-100.2R

	Constant Voltage	Constant Current
OUTPUT VOLTAGE:	Zero to 100 volts	100 volts maximum
OUTPUT CURRENT:	200 milliamps maximum	Zero to 100 mA (available to 200 mA at extra charge)
RESOLUTION:	1 mV	1 μA
LOAD REGULATION: (no load to full load) (zero to maximum resistance)	Better than 0.0001% or 20 μV, whichever is greater	Better than 0.0001% or 100 nA, whichever is greater
LINE REGULATION: (10% line voltage change)	Better than 0.0001% or 20 μV, whichever is greater	Better than 0.0001% or 100 nA, at any setting
ABSOLUTE ACCURACY OF SETTING:	.01% of FS	.02% of FS
NOISE: (at any load) (combined noise, hum, ripple and spikes)	100 μV p-p	Less than 1 μA p-p
SHORT TERM STABILITY: (at constant ambient temperature) Maximum 100 hour drift after 1 hour warm-up period	0.001% or 100 μV, whichever is greater	0.001% or 100 nA, whichever is greater
LONG TERM STABILITY: 1 year	0.01% or 100 μV	0.01% or 100 nA
TEMPERATURE STABILITY: (at controlled ambient temperatures from 15°C to 35°C)	Within 5 ppm/°C	Within 5ppm/°C
PRICE:	$1,500	

SEE PAGE 3 FOR ADDITIONAL GENERAL SPECIFICATIONS APPLICABLE TO ALL MODELS

SPECIFICATIONS FOR 60

CONSISTING OF MODELS



MODEL TC-602CR

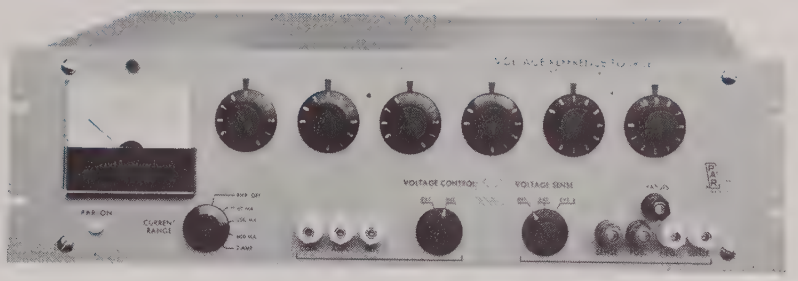
SPECIFICATIONS - MODEL TC-602CR

	Constant Voltage	Constant Current
OUTPUT VOLTAGE:	Zero to 60 volts	60 volts maximum
OUTPUT CURRENT:	2 A maximum	Zero to 2 A
OUTPUT CONTROL:		
Voltage: Selectable by panel switch in two ranges.	0 to 60.00000 volts 0 to 6.000000 volts	———
Current: Selectable by panel switch in three ranges.	———	0 to 2.000000 A 0 to 600.0000 mA 0 to 60.00000 mA
RIPPLE: (At any load) (Combined effects of all output AC components)	Less than 50 μV rms	Less than 1 microamp p-p
TEMPERATURE STABILITY: (At controlled ambient temperatures 15°C to 35°C)	Within 5 ppm/°C	Within 5 ppm/°C

			60 mA Range	600 mA Range	2 A Range
LOAD REGULATION: (No load to full load) (Zero to maximum resistance)	Better than 0.0001% or 20 μV, whichever is greater		0.0001% FS	0.0001% FS	0.0002% FS
LINE REGULATION: (10% line voltage change)	Better than 0.0001% or 20 μV, whichever is greater		0.0001% FS	0.0001% FS	0.0002% FS
	6 V Range	**60 V Range**			
ABSOLUTE ACCURACY:	0.01% or 100 μV	0.01% or 1 mV	0.01% or 1 μA	0.01% or 10 μA	0.01% or 200 μA
SHORT TERM STABILITY: (At constant ambient temperature) Maximum 100 hour drift after 1 hour warm-up period.	0.001% or 6 μV	0.001% or 20 μV	0.001% or 60 nA	0.001% or 600 nA	0.001% or 20 μA
LONG TERM STABILITY: (1 year)	0.01% or 100 μV	0.01% or 100 μV	0.01% or 60 nA	0.01% or 600 nA	0.01% or 20 μA
PRICE:	$1,750				

VOLT, 2 AMP SERIES

TC-602CR AND TC-260R



MODEL TC-260R

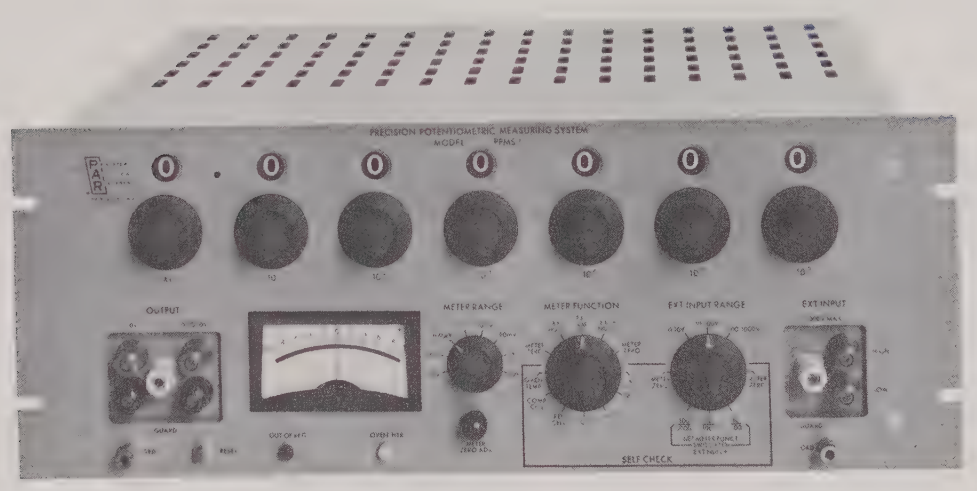
SPECIFICATIONS - MODEL TC-260R

OUTPUT VOLTAGE:	Zero to 60 volts
OUTPUT VOLTAGE CONTROL:	Output voltage is continuously adjustable to within 20 microvolt potentiometer resolution. Voltage setting is read out on six front panel digital dials.
ABSOLUTE ACCURACY OF VOLTAGE SETTING:	0.01% or 1 mV
OUTPUT CURRENT:	Zero to 2 A
OUTPUT CURRENT LIMITING:	Output current range and metering are selectable by a front panel switch and limited electronically to 60 mA, 200 mA, 600 mA and 2 A.
LOAD REGULATION (No load to full load):	Better than 0.0001% or 20 μV, whichever is greater
LINE REGULATION (10% line voltage change):	Better than 0.0001% or 20 μV, whichever is greater
RIPPLE (At any load):	Combined effects of all AC components in the output are less than 50 μV rms.
SHORT TERM STABILITY (100 hours at constant ambient temperature):	After a one hour warm-up period, the output voltage will not drift by more than 0.001% or 100 μV, whichever is greater.
LONG TERM STABILITY (1 year):	0.01% + 100 μV
TEMPERATURE STABILITY (15°C to 35°C):	At controlled ambient temperatures between 15°C and 35°C the output voltage will remain constant within 5 ppm/°C.
CONSTANT CURRENT OPERATION:	Adaptable to constant current operation by the addition of external resistors and feedback to the SENSE terminals. Stability in constant current mode 0.001% ± stability of resistors.
PRICE:	$1,250

SEE PAGE 3 FOR ADDITIONAL GENERAL SPECIFICATIONS APPLICABLE TO ALL MODELS

PRECISION POTENTIOMETRIC MEASURING SYSTEM

MODEL PPMS-1



The Model PPMS-1 is a self-contained system with the basic components for making parts/million measurements of external resistance ratios or DC voltages up to 1000 volts. In addition, since this unit contains an ultra-stable DC reference source, it can function as the controlling elements for highly-accurate voltage or current supplies where higher output power is required. Power amplifiers with current capacities to 5A or voltage capabilities to 1000 volts are available from PAR as optional accessory equipment.

The Model PPMS-1 consists of a 10-volt DC source with its saturated standard cell reference, along with other critical elements, housed in a proportional temperature-controlled oven. Also included are a self-checking seven-digit Kelvin-Varley divider, a null indicator having a basic sensitivity of 1 microvolt full scale and precision voltage dividers to scale down externally-applied voltages to within the primary range of 10 volts. A second standard cell, known as the comparison cell, is included for checking the working standard cell reference.

An output signal fully isolated from, but proportional to, the deflection of the null meter is provided for driving strip-chart and other recorders. Thus, the unit can also function as a self-contained monitor of the stability of other voltage supplies.

A unique method of self-checking the four most significant decades of the Kelvin-Varley divider WITHOUT additional equipment is built in. The built-in circuitry also provides for verifying oven temperature and monitoring standard cell voltage and for observing the resistance of the voltage divider.

GENERAL SPECIFICATIONS

The Model PPMS-1 provides two primary outputs: 1) a constant output voltage of 10 volts for load currents up to 25 milliamps to energize external resistance networks for ratio measurements, 2) a seven-digit Kelvin-Varley divider output (derived from the constant 10 volt output) which is adjustable from 0 to 10 volts with a maximum source impedance of 10 k ohms.

Both outputs are completely floating with respect to chassis ground and the internal shield. In addition, overload or short circuit of the output will not damage the unit.

INPUT POWER: 105-125 or 210-250 volts; 50-60 Hz; 25 watts

SIZE: 19"W x 7"H x 19"D

WEIGHT: Approximately 45 lbs. (Because of the standard cells, it is recommended that unit be stored and operated in a horizontal position.)

ENVIRONMENT: Ambient temperature range of 15°C to 30°C with relative humidities not exceeding 60%

PRICE: $4,950. Export prices approximately 5% higher (except Canada.)

WARRANTY: One year

Specifications & Prices Subject to Change Without Notice

VARIABLE OUTPUT (0-10.000000 VDC) SPECIFICATIONS

SOURCE IMPEDANCE: 10 k ohms maximum

RESOLUTION: 1 microvolt

ACCURACY: Within ±10 ppm of setting ±10 microvolts

NOISE (open circuit): Combined ripple, noise and spikes within 10 microvolts rms

LINE REGULATION (10% line voltage change): Within 0.5 ppm

SHORT TERM STABILITY: Within ±1 ppm ±1 microvolt of setting per 24 hours

LONG TERM STABILITY: Within ±5 ppm of setting ±5 microvolts per year

RECORDER DRIVE OUTPUT: Adjustable from 0 to 1 V (1 mA max. current) (Output of null Detector, proportional to, but isolated from Panel Meter)

CONSTANT OUTPUT (10.000000 VDC) SPECIFICATIONS

ACCURACY: Output within 10 ppm of 10 volts (traceable to N.B.S.) at shipment

CURRENT: 25 milliamps maximum

LOAD REGULATION: Output changes no more than 0.5 ppm from zero to full load

LINE REGULATION:
STABILITY:
NOISE: } Same as specified above for VARIABLE OUTPUT at full scale setting

TRANSIENT RESPONSE: Output recovers to within 1 millivolt of steady state voltage in less than 25 microseconds following application or removal of full load; full recovery within 1 millisecond.

TEMPERATURE STABILITY (15°C to 30°C): ±0.2 ppm per degree C.

EXTERNAL INPUT DIVIDER SPECIFICATIONS

The guarded divider network divides input voltages extending up to 1000 volts by a factor of ten or one hundred for potentiometric measurements within the 10 volt primary range of the unit. Input voltage and impedance, as well as accuracy and stability of the division factors of the divider network as a function of the setting of the range switch, are as follows:

Input Range Switch Setting	Input Impedance At Null	Initial Accuracy*	Stability
0-10V	Open Circuit	—	—
10-100V	100k ±0.1%	25 ppm	25 ppm/year
100-1000V	1 Meg ±0.2%	25 ppm	25 ppm/year

By using the internal self-calibration feature, the ratio of the external input divider may be compared to the Kelvin-Varley divider. This allows improvements in the accuracy and stability of the extended voltage measuring capability of the instrument.

SPECIAL FIXED OUTPUT REFERENCE SOURCES

OUTPUT:

Constant Voltage: Any fixed output to 100 volts at 2 A maximum
Constant Current: Any fixed output to 2 A at 100 volts maximum

OUTPUT CONTROL:

Constant Voltage: Any desired range about nominal with resolution up to 1 ppm of range, standard resolution 220 ppm
Constant Current:

LOAD REGULATION (no load to full load):

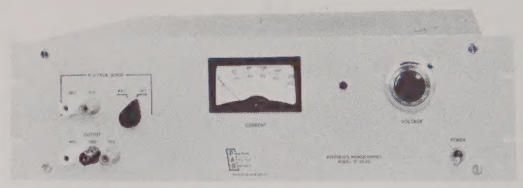
Constant Voltage: Better than 0.0001% or 20 μV, whichever greater
Constant Current: Better than 0.005% or 1 μA, whichever greater

LINE REGULATION (10% line voltage Change):

Constant Voltage: Better than 0.0001% or 20 μV, whichever greater
Constant Current: Better than 100 nA

NOISE (at any load) (combined ripple, hum, noise and spikes):

Constant Voltage: Less than 200 μV p-p
Constant Current: Less than 1 μA p-p



SHORT TERM STABILITY (100 hours at constant ambient temperature after 1 hour warm-up):

Constant Voltage: Better than $\pm$0.001%
Constant Current: Better than $\pm$0.002%

TEMPERATURE STABILITY (from 15°C to 35°C):

Constant Voltage: 5 ppm/°C over complete range
Constant Current: 5 ppm/°C over complete range

PRICE: By quotation only

AVAILABILITY: Custom built to order in approximately 90 days

SEE PAGE 3 FOR ADDITIONAL GENERAL SPECIFICATIONS APPLICABLE TO ALL MODELS

PRINCETON APPLIED RESEARCH CORPORATION SALES OFFICES

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F. Y. Gates Company, Inc.
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Albuquerque, N. M. 87100
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Cambridge, Mass. 02138
Tel: (617) 491-6800

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Charlotte, N. C. 28209
Tel: (704) 523-9121

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LaGrange Industrial Park
LaGrange, Illinois 60526
Tel: (312) 354-0660

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2245 Warrensville Center Road
Cleveland, Ohio 44118
Tel: (216) 371-5335

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1954 North Main Street
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Tel.: (513) 277-3822

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Englewood, Colorado 80110
Tel.: (303) 761-0591.

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Tiby Company
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Minneapolis
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Minneapolis, Minn. 55423
Tel: (612) 866-1700

Montreal
Ahearn & Soper, Ltd.
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Montreal 28, Quebec
Tel: (514) 482-9750

Orlando
Technical Associates, Inc.
2319 East South Street
Orlando, Florida 32803
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Salt Lake City
F. Y. Gates Company, Inc.
455 East Fourth Street
Suite 311
Salt Lake City, Utah 84111
Tel: (801) 359-1101

San Francisco
O'Halloran Associates
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Palo Alto, Calif. 94303
Tel: (415) 326-1493

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Seattle
Avionics Liaison, Inc.
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Seattle, Washington 98108
Tel: (206) 723-7602

Toronto
Ahearn & Soper, Ltd.
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Toronto 19, Ontario
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4922 St. Elmo Avenue
Bethesda, Maryland 20014
Tel: (301) 652-5110

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50 Rockefeller Plaza
Room 916
New York, New York 10020
Tel: (212) 245-0444

Export (except Europe)
Henley & Company
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New York, New York 10017
Tel.: (212) 986-5544

FOREIGN REPRESENTATIVES

Argentina
Coasin S. A.
Virrey Del Pina 4071
Buenos Aires
Tel: 52-3185

Australia
Tecnico Electronics Pty. Ltd.
566 Elizabeth Street
Melbourne
Tel: 34-3694

Austria
International Engineering Service
Etschnerweg, 48
Vienna 14

Brazil
Digimatic Ltd.
P. O. Box 19027
Sao Paulo 15

Denmark
Christian Rovsing Ltd.
51, Rodovrevej
Rodovre
Copenhagen
Tel: (01) 41-10-11

Finland
Havulinna Oy
Vuorikatu 16
P. O. Box 10468
Helsinki 10
Tel: 61451

West Germany
Nucletron Vertriebs GmbH
8 Munich 54
Gaertnerstrasse 60
Tel: (0811) 546081

India
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Tel: 264592

Israel
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Tel Aviv
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Italy
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Japan
Rikei Trading Co., Ltd.
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Tokyo
Tel: (591) 5246

Netherlands
Nenimij NV
16 Nassau Dillenburgstraat
The Hague
070-24 44 96

Norway
Hugo Riso
P. O. Box 8 Taasen
Oslo 8
Tel: 23 25 80

South Africa
Electronic Research Labs. Pty, Ltd.
P. O. Box 10523
Johannesburg
Tel: 23-1705

Sweden
Teleinstrument AB
Box 14
Stockholm-Vallingby
Tel: 87 03 45

Switzerland
Resistronic AC
Hugistrasse 3
2500 Biel
Tel: 032 356 66

Taiwan
Industrial Electronics, Ltd.
89-2 Lane 75
Nanking East Road
4th Section
Taipei
Tel: 22423

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